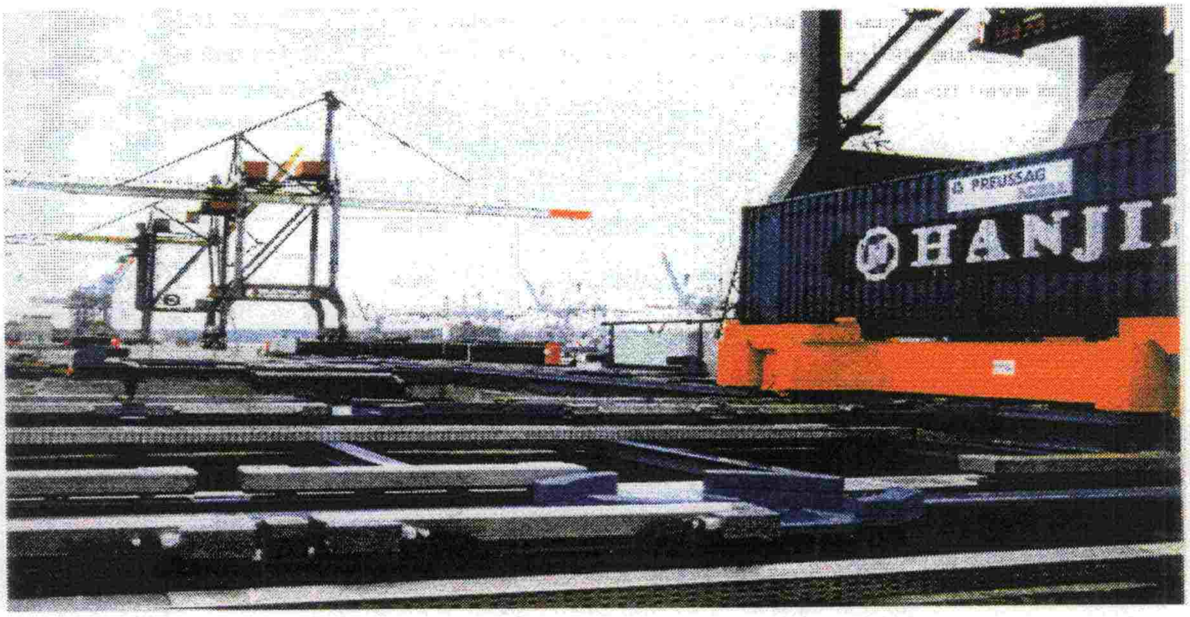
Publications of The Finnish Maritime Administration 4/99

Automation and mechanisation of cargo handling in Finnish ports and ships



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Seppo Holmberg, Head of Consortium, EP	Research study
Esa Eerikäinen, Jani Tikkanen, EP-Logistics Ltd	Assigned by Ministry of Transport and Communications & Finnish Maritime Administration
Risto Aapro, Suunnittelukeskus Ltd	

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Automation and mechanisation of cargo handling in Finnish ports and ships

Abstract

The increasing unitisation of cargo in foreign trade and the growing knowledge on costs involved as well as difficulties with labour resources have induced intentions towards other means of cargo handling in port environment. One supporting element to this trend is the innovations made within the shipbuilding industry. In one these factors have set requirements on the development and implementation of automation and mechatronics in the scope of terminal operations.

In the future it is possible to drift to a situation, where the conventional terminal concept is not applicable to meet the enhanced standards of e.g. intermodalism. The terminal areas expand constantly. To control and avoid this kind of unnecessary growth new concepts have to be invented. In essence this requires more efficient handling equipment, possibilities to flexible use of resources. Other imaginable approach is to decrease the throughput times in terminal or to reduce cargo handling in port. The shipping market is nowadays extremely customer oriented. For ports this means maximisation the overall effectiveness and the services provided have to be invariably available. Since the costs can not be diminished unlimitedly, the automation of activities is a logical solution to confront the altered situation.

The tendencies of cargo handling automation in Finland are studied in this context comprehensively covering the whole transport chain. This allowed taking the interests of basic industry into consideration, what is inevitable when developing new systems and models. It should be emphasised that all operating parties involved are obliged to participate in development projects.

The versatility is common to all Finnish ports. Supplied services in almost every port cover the variety of different means of maritime transportation. The lack of specialisation in ports generates many obstacles in the implementing process of automated systems. The automation in Finnish port sector is taking its first steps. There is not any comprehensive system in use. There exist some individual development projects on experimental level in few ports. The most potential target for automation in the near future is related to the handling operations of containers and other cargo units.

Keywords

automation, intermodalism, transport chain, cargo handling, unitisation

Miscellaneous

A Cd-rom is published also. The contents are identical, even if there is some additional information included in multimedia product.

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PREFACE

The structural change in the forest industry, a branch of vital importance to Finland, began some years ago and is still continuing. Activities are being concentrated into the hands of fewer and larger companies. The forest industry is becoming more globalised, as companies expand their operations from traditional market areas to new continents. This sets new demands with regard to the automation of cargo handling, but at the same time it opens up new opportunities for the development of handling systems.

Cargo handling costs are directly related to the extent to which the available resources, space, technology, and intelligence of technical control systems are utilised. In the context of this study, the concept of technology or techniques covers the machinery and equipment used for moving and handling the cargo units within the port area. There is a wide range of reliable equipment and devices available for these purposes, and it is hardly possible to make any major improvements in their efficiency, utilisation rate and maintenance. The only important field which is seen to have real potential for further development is in the control systems for cargo handling operations.

Intelligent control systems have been in use for quite some time in different industrial plants and storage areas other than ports. Without these electronic data management systems it would be impossible to control and manage these complex material flow systems economically.

Transportation and handling systems are designed on the basis of geographical conditions and infrastructure, taking into account the quantity and required quality of the transport services. The growing demands on delivery speed and accuracy of information, together with real-time data on the exact location of the goods at each moment, have led to a situation in which the speed and reliability of the systems have reached a point where human capacity is no longer sufficient for controlling these operations manually. Good services to port customers thus require automated materials handling and real-time data management. The need is further emphasised by customer requirements for maximum efficiency and all-time availability of services. At the same time, the costs of the handling system used by the port operator should be minimised.

Quite recently, the adoption of automation has also become a topic of discussion in ports. The necessary components are all there for the automation of the ports' materials handling systems.

The present study examines the current status of port automation in Finland, and compares it to the situation at the international level. The study is part of a comprehensive research project entitled "Development of Finland's Sea Infrastructure 1995-1998", with financing from the EU's TEN-budget. The aim is to study the economic and technical conditions for automated handling and management of different types of cargo, and to determine the possibilities for reducing costs and cargo damages, and improving time management in the Finnish ports.

The following studies have been carried out earlier as a part of the comprehensive research project:

- Development of Winter Navigation
- Development of New Ice-breaker Type; Finnish Maritime Administration, FMA
- Development of Ice-breaker Data System (IB-Data); FMA (in Swedish)
- Development of Winter Navigation in Inland Waterborne Traffic; FMA
- Development of Integrated Maritime Transport
- Direct Maritime Transport to Central Europe; FMA/Ministry of Transport and Communications, MTC
- Development of New Vessel Types
- Logistic Background Study (Sea Bridge Concepts); FMA/MTC
- Securing Finnish Marine Connections
- Background Study (Finland's Sea Bridges); MTC
- Effects of Transit-Traffic on the National Economy
- Effective and Fair Pricing of Maritime Transport; FMA/MTC

This study on port automation, "Automation and Mechanisation of Cargo Handling in Finnish Ports and Vessels", was commissioned by:

Shipping Unit of the Ministry of Transport and Communications of Finland, and
Hydrography and Waterways Department of the Finnish Maritime Administration.

The following project management group supervised the implementation of the study:

Mr. Taneli Antikainen, Finnish Maritime Administration
Mr. Sauli Eloranta, Kvaerner Masa-Yards Inc.
Mr. Harry Favorin, Ministry of Transport and Communications
Mr. Torsten Grandell, Transfennica Oy
Mr. Hans Martin, Finnsteve Oy
Mr. Jouko Vuoristo, Finnish Maritime Administration

The study was initiated in August 1997 and completed on 12 December 1998.

The study was conducted by the following team:

Mr. Esa Eerikäinen, EP-Logistics Oy
Mr. Seppo Holmberg, EP-Logistics Oy
Mr. Asko Sipari, EP-Logistics Oy
Mr. Jani Tikkanen, EP-Logistics Oy
Mr. Risto Aapro, Plancenter Ltd.
Mr. Jorma Nummenpää, Plancenter Ltd.

The findings are published in a report within the MTC series of publications. The report will be formally presented at the Jugend Hall of the Ministry of Transport and Communications in Helsinki on 3 February 1999.

1. SCOPE OF WORK, TERMINOLOGY AND ABBREVIATIONS

1.1 Scope

The main targets of this study are the product groups of the chemical and mechanical forest industry, as well as such other products whose packing mode, size and weight fulfil the basic requirements for automatic handling. This category includes, e.g., palletised products and containers.

Bulk products are excluded from the scope of this study.

The study analyses the technical compatibility of the cargo and the vessel, as well as the possibilities to increase the automation level of cargo handling at port.

The control and management systems related to materials handling are not included in the study. Their significance and development needs as a subcomponent of automation are only dealt with to the degree of the detail necessary in the given context.

1.2 Terminology and Abbreviations

Because of the specialised nature of port terminology, the most important expressions and abbreviations used in the text are presented at the beginning of the report to facilitate reading. The vocabulary is explained in a somewhat broader sense than might be necessary to support the text.

Automatic guided vehicle, AGV: Automatically controlled transport/transfer vehicle.

Automation: Repeated operation of a machine or other device, the operation and control of which are based on signals identified by its own sensors independent of human intervention. The degree of automation is determined by the level of external intervention in the operation of a machine or device.

Cassette: Wheelless cargo platform moved by a transfer vehicle.

Container: solid, standard-size flat made from metal, length 10 ft., 20 ft., 30 ft., 40 ft. or 45 ft., and equipped with ends, sides, roof, refrigeration, etc., as defined by international model codes. The maximum load, dimensioning of the lifting points in the box corners, and the number and letter series used for identification, are also determined by international standards.

Continent: A commercial and shipping concept covering the ports of Continental Europe from Hamburg to Le Havre, sometimes also including Gibraltar; often specified by a regional clause (Hamburg - Le Havre" or "Hamburg - Gibraltar").

Conventional ship: Ship whose loading and discharging is carried out with shore cranes or with the vessel's own derricks.

EDI: Electronic data interchange between organisations.

Front-loader truck, FLT: Basic vehicle for mechanised (electricity, LPG, diesel) materials handling. During lifting and driving the load is located outside the truck's own framework. The load is lifted vertically with a mast attached to the chassis.

Intermodal traffic: Chain of transport in which the same unit is transported unopened using two or more modes of transport.

ISTEA Act: Intermodal Surface Transportation Efficiency Act passed in the USA for the development and monitoring of intermodal traffic.

Mechanisation: Repeated and regular performance by a mechanical instrument or device whose operation and control are based on signals given by a human operator.

Mechatronics: Term coined from the words 'mechanics' and 'electronics', implying a combination of informatics, mechanics and electronics for the purpose of improving the intelligence level as well as the flexibility, economy and reliability of machinery and equipment.

Mega-Hub: Container handling system for trains and trucks at land terminals, developed by the German company Preussage Noell.

Operator (stevedore): Company specialised in the physical handling of goods and the related logistic services.

Port: Enclosed area, having the necessary facilities for smooth materials handling and storage related to maritime and surface transport equipment. In Finland, the land and water areas belonging to the port, as well as their infrastructure, are usually owned by the municipality or the Port Authority.

Port Authority, PA: In Finland, public ports are part of the municipal administration, mainly as public utilities. The PA is responsible for port administration and infrastructure, and provides support services for traffic and cargo handling. The division of responsibilities between the PA and the operator varies from port to port.

Port dues: Fees charged by the port owner for ship and cargo as well as for waste management services.

Reach stacker, RS: Equipment mainly designed to handle heavy cargoes outside its own framework. The load is lifted vertically with a telescopic spreader beam by means of a gripping device. As the name implies, the equipment has a wide outreach.

Roll-on / roll-off ship, RoRo ship: Vessel designed to have its cargoes driven or towed by terminal tractors on and off ship, e.g. through the stern door.

Rubber-tyred gantry, RTG: Crane for storing of containers and marshalling for road and rail traffic at the container terminal.

Ship-to-shore gantry, SSG: Lifting equipment used to move containers between ship and shore.

Shortsea shipping: In contrast to deepsea traffic, shortsea shipping covers feed traffic over relatively short distances, which is typical, e.g., of international marine transport between Finland and other countries.

Side door, SiDo: Enables cargo handling through the side of a ship, usually a structure fitted to the starboard of a RoRo vessel through which part of the goods can be loaded.

Sling: A hoisting rope, belt or cable loop for lifting loads.

Spreader: Fixed or adjustable device attached to a crane, for lifting ISO containers and frames.

Stern door: Hinged bridge of a vessel by which a RoRo ship is connected with the berth.

Stowable roll-on/roll-off, StoRo: Cargo handling method whereby the cargo is towed on board with terminal tractors and trailers, unloaded from the trailer with a lift truck and placed on the deck of the vessel.

Straddle carrier, SC: Vehicle originally designed for moving timber products, later on for moving containers within its own framework.

Stripping: Unloading a shipping container or trailer.

Stuffing: Loading a shipping container or trailer.

Terminal: Site or warehouse where consignments are packed, grouped, re-loaded and unitised, as well as stored for short periods between transports, if necessary.

Terminal trailer: Wheeled under-carriage towed by a terminal tractor.

Transit: Transportation of merchandise from one country to another through a third country without customs clearance in that country.

Twenty foot equivalent unit, t.e.u.: Unit of measurement equivalent to one 20 ft. (6 m) shipping container.

Twistlock: A standard cargo and container locking device for securing the unit to the lifting device, transfer vehicle or other equipment.

2. INTRODUCTION

2.1 General

The development of intermodal traffic in the USA in the mid-1980s has greatly influenced the growth of marine traffic, improved port efficiency and increased competition. Correspondingly, in Europe, the goals of intermodal thinking are the same, but from different starting points[1]. Considerable investments are being made today in environmental protection. The development of intermodal transportation aims at directing the flows of traffic and goods from the highways to railways and waterborne transport.

The intermodal concept not only produces ecological improvements such as less air pollution, noise and congestions, but also economic advantages. The development of intermodal traffic, both in goods and passenger transport, is a part of the national competitiveness strategy of the USA. In Europe also it has an important position. The EU is currently implementing more than 50 intermodal development projects. In the USA, these projects are carried out under the ISTEA Act, according to which a total of USD 155 billion should have been invested into intermodal development during a period of 6 years. This investment goal has not, however, been fully reached.

Commercial transport accounts for approximately 7% of the GNP in most countries, and its efficiency thus is quite significant for national competitiveness. The logistics costs in Finland are higher than in other countries due to the extra costs incurred by winter navigation, among other things. The estimated logistics costs rise to FIM 70 billion per year, i.e., over 10% of Finland's GNP.

In most countries, ports are the major junction points of intermodal traffic. The economic profitability of ships is dependent, above all, on speedy loading and discharging.

For example, the expanding use of containers and other massive units makes it possible to increase automation in cargo handling in ships and ports by means of existing techniques, and by applying technical solutions from other fields as well.

Of all modes of shipping, container transports are increasing most rapidly, and the trend is to containerise products such as paper as well as a part of chemical products. Approximately 10% of the Finnish marine traffic tonnage is shipped in containers. Some 20% of the paper exported from Finland is containerised. Around half of all Finnish container traffic passes through the port of Helsinki.

Large carriers for container, unit and bulk cargoes are used for intercontinental transport, usually with one loading and one discharging port. The Finnish mercantile fleet, on the other hand, is highly specialised. The specific features of Finnish shipping include a short turnaround time at port, unitised cargoes, high technological development, and a demanding natural environment. These have made it necessary to specialise the vessels as well.

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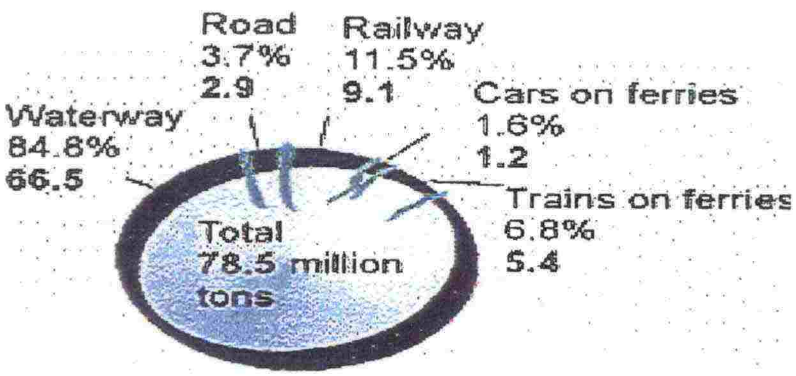
[11] Intermodal traffic in the USA was prompted by the liberalisation of competition in the early 1980s and the subsequent railway traffic connecting the marine traffic of the east and west coast. Trains up to 2 km long carried stacks of two containers on top of each other, i.e., even more than 500 TEU per train. The use of inter-coastal trains expedited traffic by 1-2 weeks compared to plain maritime transport. In Europe the impelling force was air pollution and congestion of road traffic in most of the Central European countries.

Finnish public ports, however, have not been able to specialise, e.g., because of the rather limited flow of merchandise. Helsinki is a notable exception. For a number of years already, Helsinki has distinctly aimed at specialising as a unit cargo port.

During 1997, some 90 tonnes of different types of goods were handled in Finnish ports. The share of liquid and bulk products of the foreign traffic was 54% (FMA: Maritime Traffic Between Finland and Foreign Countries 1997). The cargo handling systems in bulk traffic are highly automated or mechanised, representing advanced modern technology. The handling of general and unit cargoes in Finnish ports, on the other hand, is still manual.

Figure 1. Distribution of overseas traffic by mode of transport, excluding transit traffic (MTC 1996).



The physical properties of wood and metal industry products and their overall manageability during the transport chain set high demands on the technical solutions regarding automation and mechanisation. The vigorous development of logistic systems has altered the basic structure of the whole transport operation. The product purchaser has an increasing influence on packing sizes and consignment volumes, which, in turn, affects the automation system to be adopted.

The efficiency of the transport chain may be measured in terms of time, quality, reliability, promptness, availability (frequency), and money. As a whole, a transport operation is the result of smooth cooperation between the various parties involved.

The optimum size and weight of the goods, as well as the optimum form and manageability of the packings, are of crucial importance for a smooth flow of merchandise. They should correspond as closely as possible to the utilisation of the space and weight capacity of the following transport phase. This study examines both the individual components of the transport chain as well as the efficiency of the entire chain.

2.2 Need for Mechanisation and Automation at Ports

Work at the port can be divided into three different elements: manual work, mechanised work, and work with an emphasis on know-how, including automatic data processing. These different types of work run parallel. The mechanisation of many basically simple and repeated tasks is often only partial, involving a great deal of manual work. A good example is the identification of cargo units, which still often requires the human eye as well as someone to feed the data manually into the system. In the industrialised western world, labour costs often play an important role, and another aim is to use technical solutions to decrease the share of mechanical and monotonous tasks performed by humans.

Investments into mechanisation and automation have to be economically justified. The automation of cargo handling is aimed at the following main points:

Reduced number of personnel: Increasing traffic handled by the same number of personnel.

Less waiting time and searching for goods: Less need to purchase new equipment; the personnel can concentrate on the essential issues.

Faster handling: Less need to purchase new equipment; the personnel has time to do more.

Correct prioritisation in cargo handling: Shortens 'expensive' waiting time in favour of 'cheaper' time.

Reduced damages to cargo: Decreased compensation for damages; customer satisfaction brings in more assignments.

Rapid storage circulation: Decreased invested capital of customers; customers can offer shorter delivery times.

Smaller space requirement: Less need for expansion.

Smaller quay area: Less need for expansion.

Faster loading/discharging of trucks/trains/ships: Increased profits on invested capital.

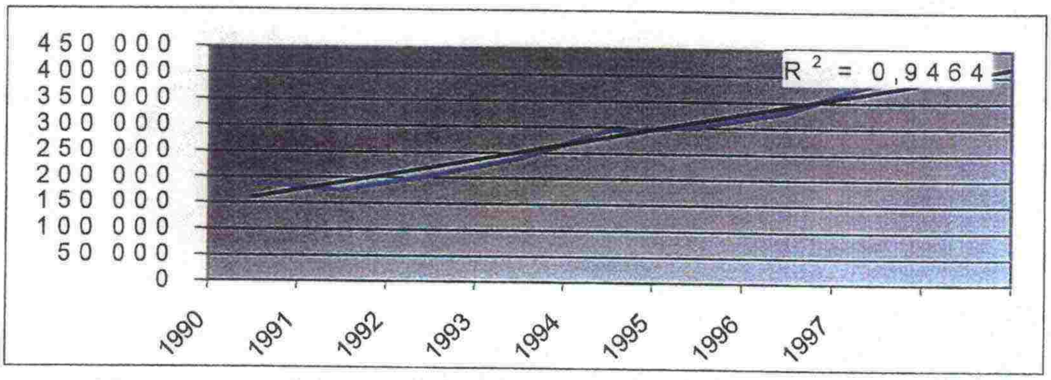
3. TRANSPORT CHAIN FROM PLANT TO PORT

3.1 Current Transport Chains

The study "Comparison and Development of the Competitiveness of Finnish Transport Companies" by Ministry of Transport and Communications (21/97) found that maintaining the condition of the goods throughout the transport chain was as a basic factor determining customer satisfaction. Each transfer or physical handling of merchandise involves a risk in this respect. Consequently, the development of the transport chain is strongly focused on decreasing the number of times that the product is directly handled physically, on minimising human errors, and on creating new types of jumbo transport platforms that are suitable for the entire chain.

The practice of loading the intermodal units at the forwarding station or at port in such a way that the next physical handling of the goods does not take place until the goods reach the recipient is becoming increasingly common in Finland (see Figure 2). Trailers and containers are included here as intermodal units.

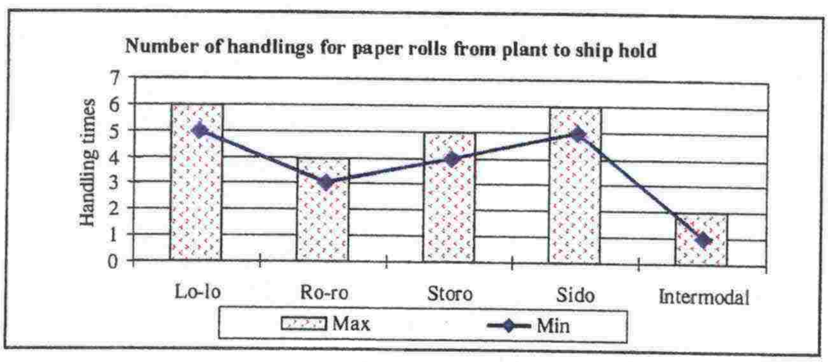
Figure 2. Increase of intermodal units in export shipments



The following section describes the current composition of the transport chain as well as its critical points from the technical or economic point of view, with respect to chemical and mechanical wood products, from plant to port and further to the vessel holds in different alternatives.

The chain has been divided into three main stages: 1) plant, 2) port and 3) ship. In unit loading each of these stages involves physical handling, which always contains the risk of damage to the merchandise.

Figure 3. Number of handlings for paper reels

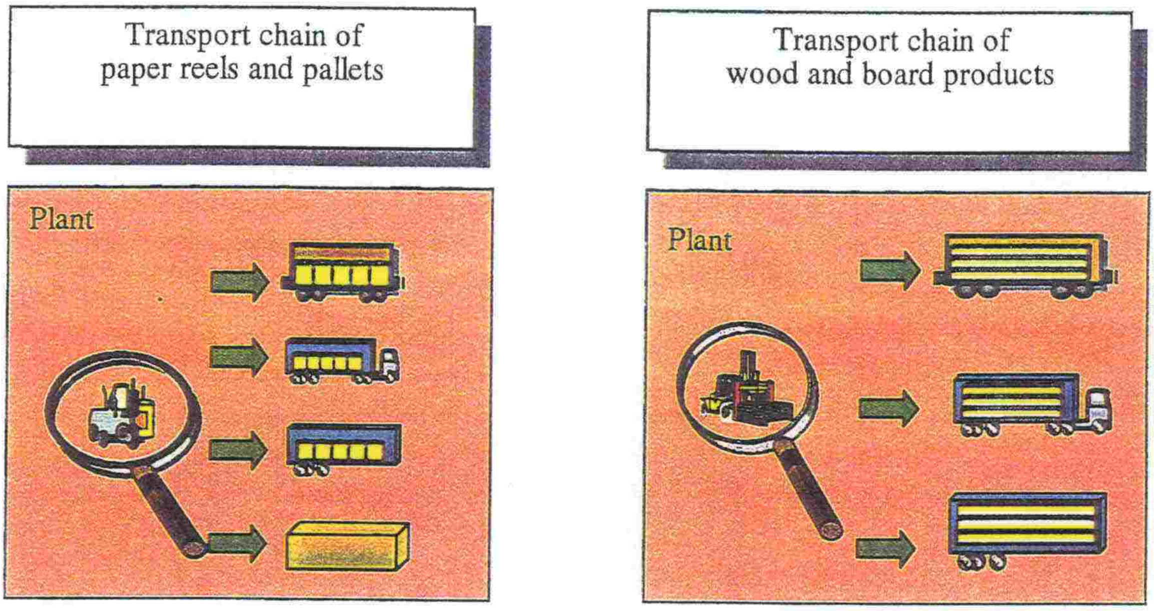


As the chemical and mechanical wood industries have several similarities from the viewpoint of technical handling and transportation they have been analysed together.

3.1.1 Handling at the Plant

Handling at the manufacturing plant is outlined in Figure 4 below. Normally it involves loading into different types of surface transport vehicles.

Figure 4. Transport Chains



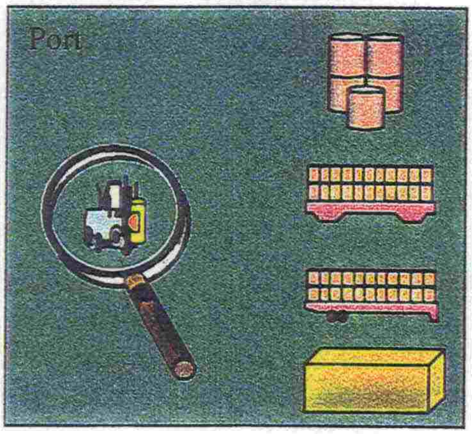
Reels / pallets	Wood / board products
Loading into rail wagons from machine or warehouse. If the destination is a port, the load is discharged and post-handled. Another alternative is a railship consignment directly to the customer.	*Loading into rail wagons from warehouse.* If the destination is a port the load is discharged and post-handled. Another alternative is a railship-consignment directly to the customer.
Loading into rail wagon with an automated system.	No automated loading.
Loading into truck. The trailer load is stripped at port; post-handling and shipping according to instructions. Intermodal unit shipping is also possible.	*Loading into truck.* The trailer load is stripped at port; post-handling and shipping according to instructions. Intermodal unit shipping is also possible.
Stuffing into trailer. Post-handling as above.	*Stuffing into trailer.* Post-handling as above.
Stuffing into container. Post-handling as an intermodal unit.	*Stuffing into container.* Post-handling as an intermodal unit.

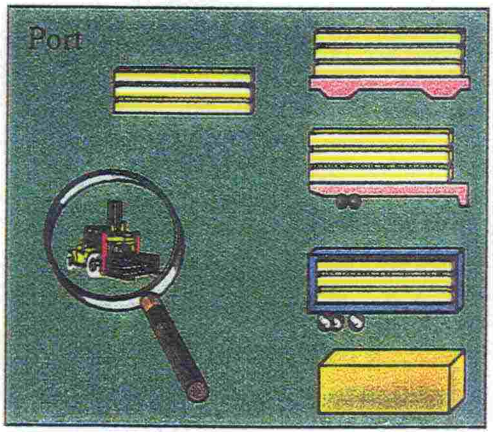
3.1.2 Handling at Port

The port operator acts according to the shipping instructions and information provided by the supplier. Advance information regarding the cargo is essential for planning of the operation and for reserving the necessary resources.

The flow-through time of the goods at port correlates with the flow of information regarding the handling of the goods. If the storage time is 0, this information should be 100%.

Figure 5. Handling at Port





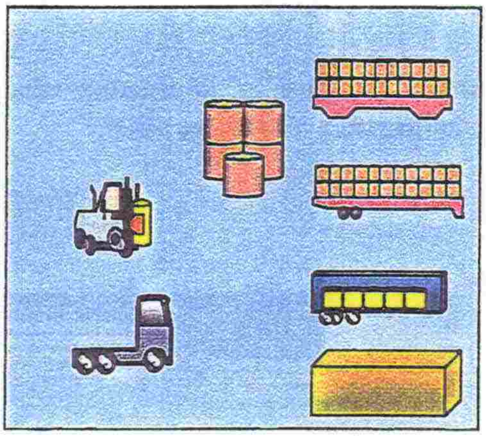
Reels / pallets	Wood / board products
Marshalling and intermediate storage before shipping; conventional and StoRo method.	*Marshalling and intermediate storage* before shipment; conventional method.
Unitisation directly from the land transport vehicle or after intermediate storage; terminal trailers, cassettes.	*Unitisation* directly from the land transport vehicle or after intermediate storage; terminal trailers, cassettes.
Containerising directly from the land transport vehicle or after intermediate storage.	*Containerising* directly from the land transport vehicle or after intermediate storage.
Reception and feeding into the computer system as *intermodal units.*	Reception and feeding into the computer system as *intermodal units.*

3.1.3 Shipping Operations

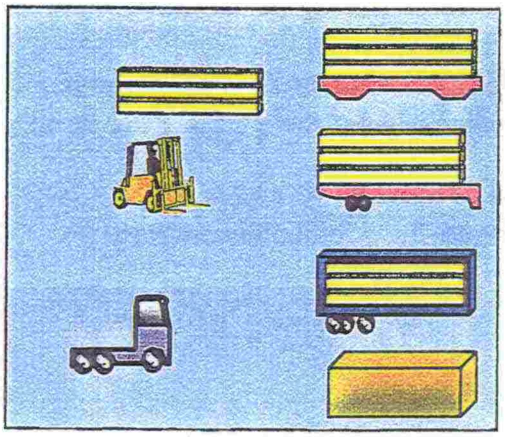
3.1.3.1 Loading

Shipping is carried out according to the shipper's instructions. Often the service level is ensured with a quality certificate. The loading operation can be divided according to the handling system as follows:

Figure 6. Different Loading Systems



Reels / pallets



Wood / board products

Reels / pallets	Wood / board products
Crane operation, LoLo system. The load is taken to the crane either directly with a lift truck or with a terminal trailer / cassette system.	*Crane operation, LoLo system.* The load is taken to the crane either directly with a lift truck or with a terminal trailer / cassette system.
Through the side door, as above.	Normally not through the side door.
StoRo system.	*StoRo system.*
Units to a cassette or terminal trailer.	*Units* to a cassette or terminal trailer.
Intermodal units with LoLo or RoRo systems.	*Intermodal units with* LoLo or RoRo systems.

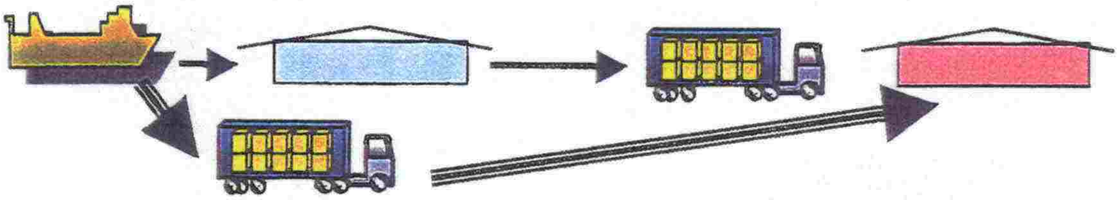
The consignment sizes in the chemical wood industry have decreased, thus increasing the turnover speed and reducing need for storage expansions. Along with a higher shipping frequency, the amount of invested capital in the warehouse decreases considerably. The above issues have been dealt with on various occasions and in several studies. They are, and should be, considered as goals that can be achieved through modern logistic monitoring methods.

3.1.3.2 Discharging Operations

Industry imports substantial quantities of raw materials yearly. A large part are imported as bulk transports or intermodal units directly to the manufacturing plant. In some cases the plant has its own port or part of a port, or a public port has made the necessary arrangements for a berth for discharging the cargo, equipped with the necessary conveyors and road transport connections.

For the leading Finnish trade groups, well functioning transport and distribution chains are both a significant marketing instrument as well as an efficient way of monitoring the course of the merchandise. They also affect the consumer prices of the products. Smooth transportation performance is of crucial importance with regard to perishable products, and calls for efficiency from all parties. Without integrated management of the transport chain, the quality of the product may deteriorate considerably, which is reflected as a decrease in demand.

Figure 7. Discharging Operations



Different kinds of fruits are imported to Finland from Europe or through the principal European ports, in the form of intermodal units, palletised, in transport trucks, trailers, containers, terminal trailers and cassettes. The port operator discharges, stores, and reloads the units into distribution vehicles. The companies specialising in fruit imports and the central wholesalers operate through their own central warehouses. Nevertheless, the trend is quite clear: rubber-tyred equipment passes through the port in a couple of hours or minutes and unloads the goods to the central warehouses or directly to shops, following modern logistics. Technical and automation applications are at their best in private central warehouses and maturing stores. The role of the port and its possibilities to influence the development of physical handling of the products are continuously diminishing.

3.2 Transport Chain Techniques

The future development of the handling and transport chains will particularly focus on areas where new and compatible information technology can be applied by all parties in the chain. The development of individual technical solutions within the chain follows the same principle: new technology will be applied in devices and equipment. The development of the transport chain as a whole requires integrated management based on a multilateral flow of information between the parties concerned.

The Finnish TEKES (Technology Development Centre), in cooperation with paper producers, ports, providers of transport services, and other specialists, has developed technical applications for the mechanisation or automation of paper transport operations. The final report "Paper Handling and Transport 2000" (1992-1996) presents the findings, the benefits to the user, and the conclusions of the study.

The importance given to the development goals in the transport chain varies depending on the line of business and specialisation of the parties concerned. For the equipment supplier, a new "invention" signifies momentary competitive advantage; the goal of the operator is to handle the largest possible tonnage of merchandise per time unit; and the producer aims at flexible management of production, sales, deliveries, and the related information flow.

Future objectives and goals may be briefly described as follows:

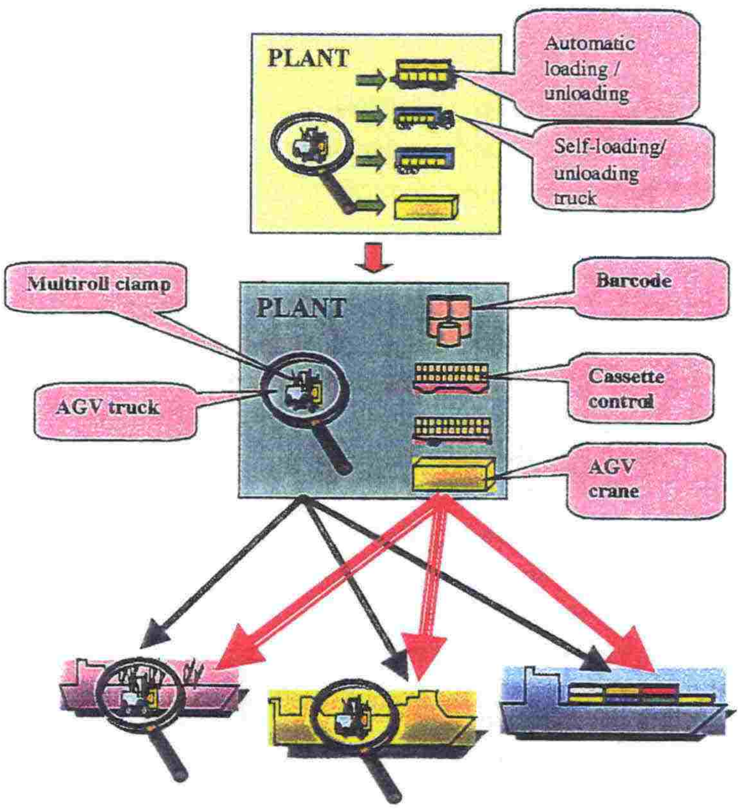
- To transfer the stuffing of intermodal units to the production plants and factories.

- To develop a multipurpose jumbo platform which is suitable both for land transport vehicles, cargo handling at port, and as a chassis in marine transport.

- To develop the identification methods, technical adaptation and telemathics of unit merchandise handling, i.e., application of automation.

An examination of the overall development trend in transportation systems and related technical solutions shows that the research results and practical measures support the conclusions that goods should be stuffed into intermodal units already at the manufacturing plant.

Figure 8. Recent Technical Developments in the Transport Chain



3.2.1 Handling at the Plant

Loading into a land transport vehicle, a container, or a jumbo platform, is based on the use of a front-loader truck (FLT) and its attachments (reel-clamps, forks). The stacking height for paper products in a road transport vehicle is low, and therefore it is seldom possible to handle many units simultaneously. However, several units of sawn timber and board products can be loaded at the same time. In some cases, as a result of cooperation between the saw and the port, sawn timber is loaded into a rail wagon and containerised as a single unit containing four bundles.

Self-unloading and self-loading vehicles have not gained the success that might have been expected on the basis of their structure. The frequency of physical load handling is not reduced, but the utilisation rate of the transport equipment grows. VR Cargo (Finnish Railways, Cargo Transportation), together with ports and manufacturing plants, has developed a system which enables the simultaneous loading/discharging of half a rail wagon: mechanical loading/unloading (UPM-Kymmene Kuusankoski plant). Practical experience has proved that the equipment makes it possible to load and unload paper reels without an additional support plate, palletised goods, as well as merchandise on different types of flats to/from rail wagons. Compared to lift truck handling, the system performs the tasks 10 or even 15 times faster. Moreover, the number of handlings is reduced if the truck carrying the load to the automated platform is equipped with a so-called multiple-reel clamp. Another significant factor is the improved utilisation rate of the railway equipment, i.e., fewer wagons and an even flow of merchandise.

If the goods are loaded alternately into rail wagons, trucks or containers, the creation of a uniform handling system is considerably more difficult than when the product warehouse is located at port and only one form of transport is used in the shipment.

Figure 9. The merchandise to be handled determines the attachments of the front-loader truck

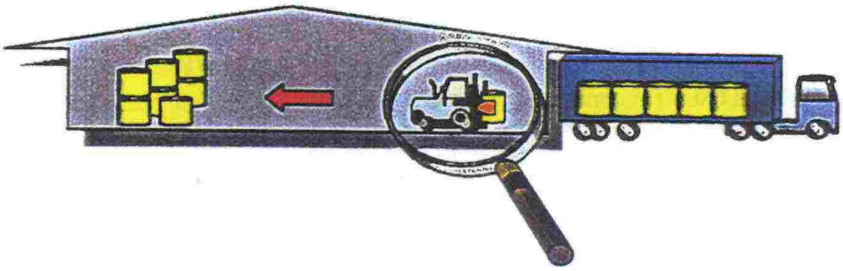
3.2.2 Handling at Port

The port operates according to the shipper's instructions and regulations. The reception, identification, storage, positioning and post-handling of the cargo depend on the shipping instructions issued by the manufacturing plant. Once the merchandise has been stuffed into its intermodal unit, it is taken after identification to the container terminal or RoRo berth.

3.2.2.1 Storage

There are two storage alternatives depending on transport distance. In the first alternative, the land transport vehicle is unloaded and the units are moved to their storage position with the same equipment, see Figure 10 below. In the other alternative, the goods are unloaded from the transport vehicle with a small machine, and a larger machine then moves the goods into their place in the warehouse together with other units.

Figure 10.



Technical solutions have been applied especially to the handling machines, and their agility, manageability and ecological properties are top-class.

Mechanised discharging of rail wagons at port does not bind manpower or machinery to the exact moment of unloading, but instead allows flexibility in overall operations. Handling in the warehouses can be performed with lift trucks equipped with multiple-reel clamps to enable several reels to be handled at the same time.

3.2.2.2 Unitisation

The strong development of logistic services enables the exchange of real-time information between the plant and the port. This makes it possible to unitise or containerise directly from the land transport vehicle (see Figure 11), thus eliminating the intermediate operations needed for storing.

Figure 11.

There are also situations in which the merchandise must first be stored and unitised later due to lack of time or space or for some other reason.

Handling is normally carried out with a front-loader truck equipped with the appropriate attachments. The efficiency of handling depends on the professional skills of the driver and the technical characteristics of the truck and its attachments.

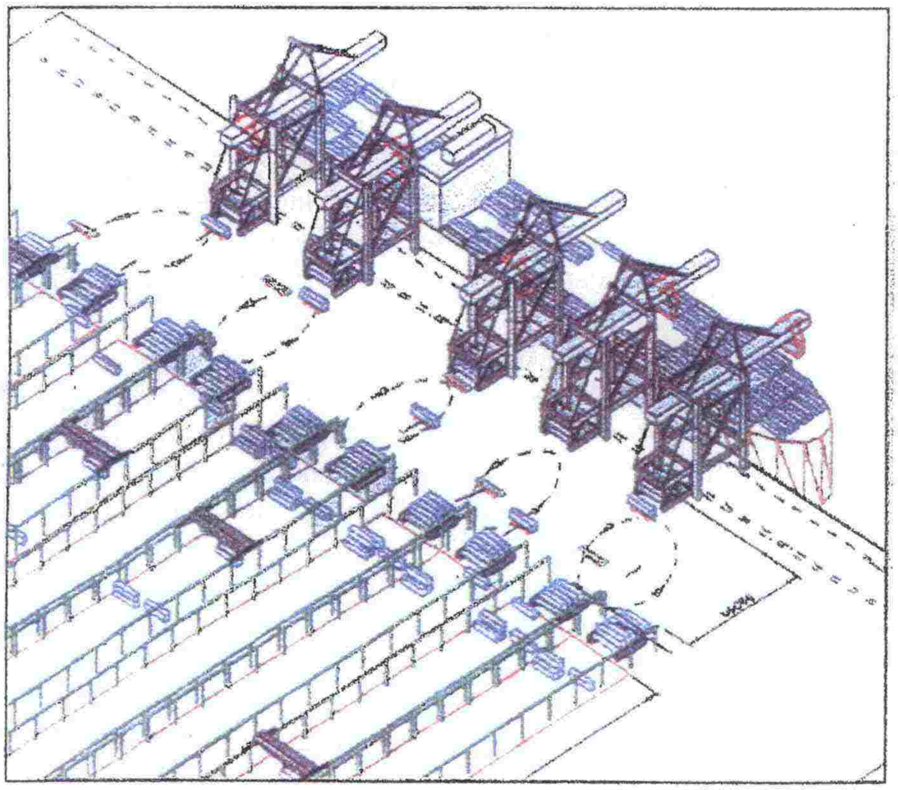
3.2.2.3 Handling of intermodal units

In Finnish as well as in overseas ports, container handling is carried out in a specific area, separate from other port operations. This is mainly due to safety aspects, the most important of which refer to the large dimensions and heavy weight of the handling machinery and cargo units.

The technique to be used depends on the handling system, which is usually determined by the cargo traffic volume. If the number of containers to be handled is small, the investment into automation does not correspond to the achieved benefits.

Figure 12 is a part of the Dutch design for optimising the operation efficiency of Post-Panamax container vessels. The calculatory target is about 50 hoists per hour per crane. The "feeding" of containers to the loading cranes represents a new operational concept. The automatic guided cranes moving in the warehouse place the containers on AGV transport trays, which carry the containers to the designated crane.

Figure 12.



For the time being, the investments in the above automatic system are too high for the numbers of containers currently handled in Finland, as the greatest benefit is gained when a vessel discharges thousands of units to be reloaded later in batches of hundreds of units.

Existing techniques make it possible to achieve very speedy lifting and driving movements, so new technology will probably be focused on raising the speed of the operations of the gripping device.

4. HANDLING SYSTEMS AND TECHNIQUES USED IN FINNISH PORTS

Roughly taken it can be said that there are two different parties operating in the ports, both of whom have it in their interest to develop the operations by procuring new equipment and developing new applications: namely, the Port Authority and the port operator.

The role of the Port Authority is to enable the automation and mechanisation of cargo handling by planning and implementing improvements into the basic infrastructure of the port. In this respect, the responsibilities of the Port Authority may be divided in four main components:

1. The navigation safety and service level of the ships using the port has to be ensured.

2. The structures of the berths and other facilities are to be easily adapted to operate the latest technology and innovations. The structures have to be strong enough to carry the loads in future handling systems.

3. Sufficient space and facilities is to be reserved for cargo handling by-operations.

4. The land transport routes to the port, including railway yards and truck parking space, have to correspond to the traffic volume.

The port operator, for its part, functions as the actual innovator of cargo handling automation and mechanisation. It investigates new technical alternatives, possibly in cooperation with the large-scale customers, so that all operative details may be satisfactory to all parties.

The role of the Port Authority in the different Finnish ports does not vary significantly. However, the alternatives adopted by the port operator for the ports may differ considerably, mainly depending on the type of merchandise to be shipped. Section 4.1 describes the present handling systems of different types of merchandise, and Section 4.2 presents the aims of the Finnish port operators regarding the adoption of new operation models.

The development trend is towards the unitisation of cargoes, whereby the number of cargo handlings and the risk of damages to the cargo may be reduced. Unitisation provides a basis for mechanised and automated cargo handling.

The development of a standard container is one of the most important innovations for bulk and breakbulk cargo handling; e.g., the lifting points are standardised. The containers are stackable, which makes the use of space efficient. Cargo handling has become easier and faster, and less labour-intensive. This, in turn, has resulted in cost efficiency and increased profitability of labour and capital.

Unitisation together with the use of trailers, terminal trailers and other towable equipment in RoRo handling results in a high handling speed, but, on the other hand, in an inefficient use of the stowage space on board, since the equipment is not stackable. The automation of this type of cargo handling is also more complicated than of container handling.

Standard units are not suitable for all types of cargoes, either for physical or quantity restrictions, such as small-size consignments. Moreover, standard units do not necessarily fit all surface transport vehicles. Therefore, there is a call for new, automated units better adapted to intermodal transport and different types of cargoes.

4.1 Handling of Different Types of Cargoes

4.1.1 Pallets

A great number of pallets enter the ports for containerising. The containers are stuffed using lift trucks, as in industrial plants. Lift trucks are also used for stripping. The number of container stuffing and stripping operations in the ports is increasing, which makes this field an interesting target for automation.

Very few automatic or semi-automatic pallet containerising systems are currently in use in Finland. One alternative would be a roller-conveyor along which pallets are driven into the container.

On the other hand, there are very many companies which manufacture automated palletising equipment. These systems are commonly used in all industrial fields. The equipment is used for palletising boxes, sacks, etc., in the desired formation.

4.1.2 Sawn timber and pulp

Sawn timber is normally transported in length-packed bundles or in truck bundles. Their width and height is about 1 m and the length varies from about 4 to 6 m. The weight is below 4 tons per bundle. Usually handling is carried out with fork-lift trucks, which unload the goods from the truck or train and store them under a shelter-roof in stacks. From the stacks the goods are taken to the berth for lifting on board with a crane.

The holds of carriers for sawn timber and pulp are normally straight-walled and the cargo is handled either with the ships' own gear or with shore cranes. This type of cargo is not easily damaged. It is usually handled in bundles and bales on pallets (pulp) and lifted in a LoLo system with slings attached to the loading device. 1-4 bundles at a time are fastened with hoisting ropes to the crane.

The automation of sawn timber materials handling is not easy. Pulp, in contrast, is quite suitable for automated containerising.

4.1.3 Paper reels

The current trend within the paper industry is towards smaller lots and special-quality papers. This reduces the possibilities for unitising, and on the other hand, a more and more diversified cargo demands a different type of handling equipment.

Paper reels are sensitive to mechanical and weather damages. In crane operation, the hydraulic head clamp mainly presses the head; if the grip is too strong, the reel may be damaged. Nevertheless, this type of clamp is gaining more ground since it does not set high demands on the packing materials.

The use of vacuum suction devices is decreasing. The side gripper easily causes damage to paper reels by altering the reel form, and thus its use is becoming less common. In on-board handling the reels are generally unitised and handled, e.g., with terminal trailers in the RoRo system or on pallets in the LoLo system.

The paper reels are unloaded from trucks or rail wagons with a lift truck with probe clamps inside the warehouse, where they are stacked for storage. The reels to be shipped are loaded directly on terminal trailers or cassettes. The reels are fastened to the trays in a lashing station, from where the ready trays are moved to an intermediate storage or under the terminal trailer shelter to wait for loading on board the ship. In RoRo loading the cassettes and terminal trailers are towed with terminal tractors on board the ship and fastened to the deck. In StoRo loading the terminal trailers and cassettes are unloaded with a lift truck and stowed conventionally directly on the ship's decks. Alternatively, the cassette or terminal trailer may be driven beside the vessel, and the reels are lifted, 4-8 at a time, on board with a LoLo system crane.

An alternative for the RoRo, StoRo and LoLo shipping of paper reels is to stuff the paper reels in a container either at port or at the plant. At present some 20% of the exported paper is containerised. According to some estimates, nearly one half of all paper shipments will be containerised in the future.

4.1.4 Containers

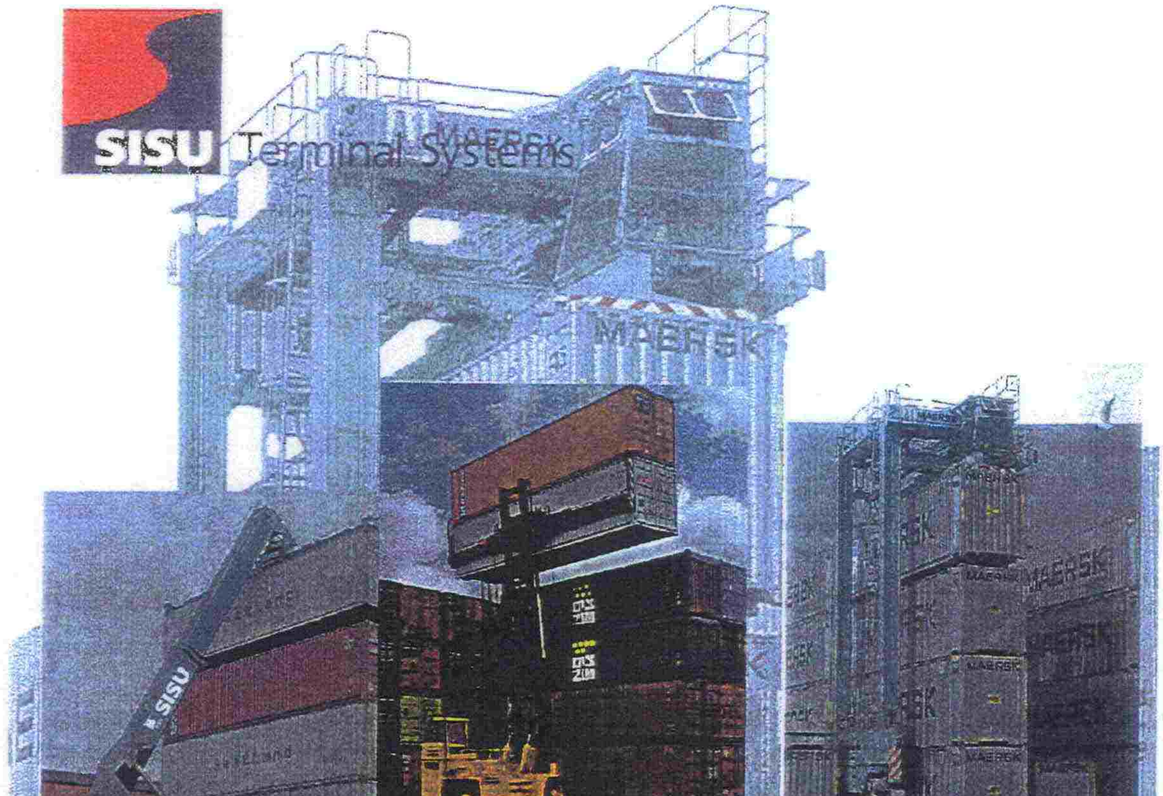
Even today, container handling in Finland is mainly carried out with reach stackers and straddle carriers. Figure 13 shows examples of the container handling equipment manufactured by the Finnish manufacturer Sisu Terminal Systems.

Some of the principal conventional container handling systems currently in use in Finland include the following:

- Straddle carriers for storing in stacks and moving (normally stacks of 3 containers).
- Rubber-tyred gantries for storing in stacks; maximum volume: a stack of 5 containers with 7 stacks side by side.
- Reach stackers for storing in stacks.
- Empty-box lift trucks for stacking empty containers.
- Cassettes (4 containers per cassette) for expediting the loading and discharging of containers to/from the ships.
- Trailers and trailer trains for container transport.
- Semi-automated cranes.

The cargo handling systems and techniques applied in different ports depend largely on the volume of the merchandise flow and the nature of the goods to be handled. Section 4.2 describes the methods and techniques used in various Finnish ports.

Figure 13. Container handling equipment



4.2 Latest Systems in Finnish Ports

4.2.1 Hamina

The port of Hamina is experiencing very strong growth in unit traffic. One of the basic causes is the transit traffic to Russia and the corresponding logistic value-added services that fall within the port's immediate sphere of influence. There are pressures to develop cargo handling in order to maintain the costs at a customer-friendly level, without neglecting the flexibility of the services.

The port is marked by a conscious focus of efforts on strategic areas where it can efficiently make use of its geographical location, future traffic forecasts, and its know-how.

The representative of the port operator has been actively involved for a number of years in the "Paper 2000" development projects coordinated by TEKES. The development work is still going on.

The objective of the various projects carried out by the port operator is to develop the automation level of Hamina port and to expedite loading and discharging by means of new mechanical solutions. The following projects may be mentioned:

- Transportation bar code: under continuous development. The code is already in partial use.

- Paper reel lift truck: a more agile and efficient truck designed in cooperation with machinery and equipment suppliers. A limited number of machines are in use. In addition, the so-called "intelligent clamp" facilitates the handling of paper reels, as it can estimate the pressing power necessary to lift the reel.

- The development of information systems related to paper transport, in cooperation with the paper industry.

- Mechanised unloading from trucks; the prototype is in the port warehouse. Test runs have given good results, but the equipment is not yet ready operationally.

- Automatic reel-stacking truck: the prototype is not in daily use, and is under further development by the VTT (Technical Research Centre of Finland).

- Pre-feasibility study for the development of unit techniques: recommendations have been made for further action.

- Special crane for loading wood products into small vessels: the basic structure is the chassis of an excavator, which has been elevated. The visibility of the driver has been improved by lifting the cabin. The operational results are very encouraging: a capacity of up to 250 m^3 per hour has been achieved.

- "Automatic trigger" for unit handling of pulp: it automatically releases the lifting hook after the load has been positioned in the stow.

- Semi-automated tray for the lifting of paper reels.

- GPS-based container positioning system (Global Positioning System).

- Acceleration gauge for use in moving the merchandise: the objective is to analyse the acceleration of different transfer modes and determine the place of a possible accident or damage during the transfer.

Mechanised truck unloading combined with the use of an automatic lift truck forms an operational entity within the reception process. The other development projects listed above represent individual technical improvements.

4.2.2 Turku

The operator company at Turku port is the same as in Helsinki. The development of operations and application of technology by the port operator can be divided into two parts: the larger development investments are studied by the central management of the operator group, whereas the operational details are the responsibility of the operator's local level. The ongoing mechanisation projects at Turku port include the following three automation and cargo handling projects:

- TV-monitor-supported entrance monitoring system at the western harbour aims at the rationalisation of operations. The system is being automated further.

- Cooperation with the forest company Metsä-Serla to sell paper products directly from the port warehouse is an improvement which decreases logistics costs.

- A tray is being developed for containerising sawn timber to ease and expedite stuffing. So far there is no collaboration with the sawmills in this project.

Future plans include a warehouse in which the cargo can be stored or moved from one transport mode and vehicle to another. The storage area has a railway track both for domestic and European track-gauge wagons, as well as the necessary loading bridges for road traffic equipment. One of the advantages is that containers can be lifted directly from one wagon to another without the need for a bogie replacement system. After the European wagons have been unloaded, they can be reloaded in the same warehouse with export cargo. In this system, terminal trailers are replaced by rail wagons. The advantage is that at both ends of the chain the rail wagon runs all the way to the customer, or at least to the nearest railway station.

Train-ferry traffic is searching for its own place among other unit traffic. The EU's internal transportation policy is aimed at transferring long-distance highway transports to waterways and railways. From this point of view, the future of Turku as one of the two train-ferry ports in Finland holds promises for long-term development, to which the port, the port operator and the shipowners operating this line can commit themselves.

4.2.3 Kotka

The port of Kotka is undergoing a phase of powerful expansion. The operations of the container terminal at Hietanen are limited by insufficient storage areas. The operator aims at meeting the challenge by changing its container handling system to a straddle carrier system, which is more effective in land use and provides temporary relief for the acute need for space.

The Port Authority is preparing for increased container traffic by moving the terminal operations within a couple of years to the deepwater port at Mussalo. The capacity of the area can be gradually taken into use. The final capacity will be 500 000 t.e.u.

According to the Port Authority, the investments into automation and the mechanisation of cargo handling operations are to be made by the immediate beneficiaries, i.e., shipping companies, operators and suppliers of the goods.

The same company acts as the port operator for Kotka and Hamina. Thus, the development of cargo handling and adoption of new technical alternatives can be seen from a wider perspective. The operator has invested in development projects based on an integrated strategy, and has discarded "secondary" development plans.

4.2.4 Pori

The port of Pori has been active in adopting new technical improvements in cargo handling and rationalisation of different work phases.

The principle used in handling dressed ore to reduce material losses dates back to the turn of the century. Accordingly, loading takes place through the warehouse roof hatches directly to the store bins. In the warehouse, the dressed ore is loaded into wagons specifically designed for this purpose by VR (Finnish Railways). The wagons are moved from the warehouse with ROLUX wagon transfer equipment. The system does not contain an automated phase.

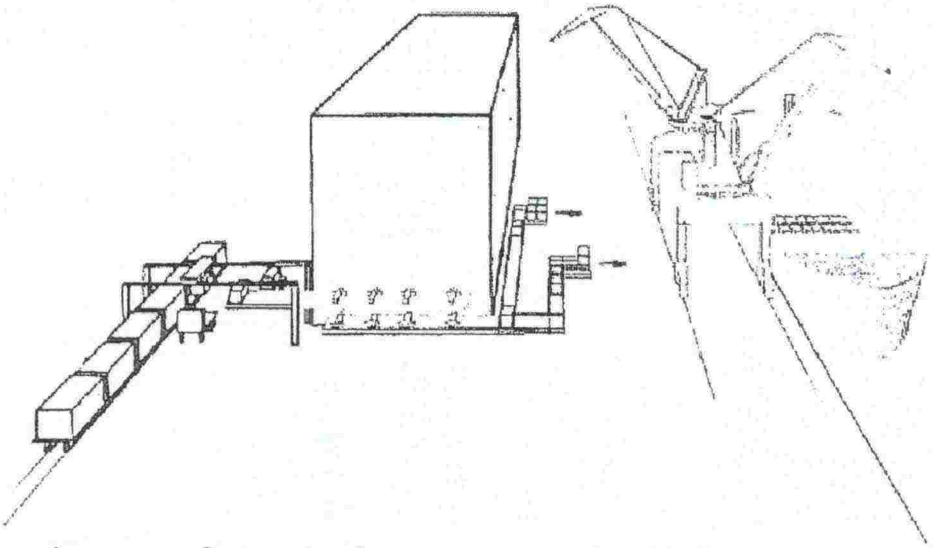
For the stowing of containers the port utilises a so-called "magic carpet". This carpet enables a generic 5-ton lift truck to stuff sawn timber in bundles of two into 40-ft. containers. The stuffing speed is about 4-5 containers per hour. The magic carpet is an innovation of the Pori port operator.

The port uses trestle equipment for storing sawn timber. The sawn timber bundles are unloaded from the train or truck and loaded transversely on trestles of a height of approximately 1 m. A trailer, backed under the storage structure, takes the bundles to the berth. The trailer can move 24 bundles at a time, compared to the present 2 to 4 bundles per trip. The full trailer is driven with a terminal tractor beside the carrier, and by lowering the trailer the bundles are placed on a similar structure as in the warehouse.

A lifting frame and remote detachment device on the crane are used for lifting and stowage of wood. This enables loading without the ship's personnel. There is a crawler-mounted equiliun crane for the loading of sawn timber. The disadvantage of this is that the berth structures have to be strengthened to support the crawlers.

The possibility of automatic high-bay of sawn timber has also been studied at Pori port. One implementation alternative is presented in Figure 14.

Figure 14. Semi-automatic handling and storage system for sawn timber



One of the most important future development targets in shipping are terminals and warehouses in which savings in time and money can be achieved by making the right choices. The model of a semi-automatic sawn timber warehouse in Figure 14 has special gantry lift trucks for unloading of rail wagons and trucks directly to conveyors, which carry the goods to a lifting system to be transferred to their correct storage place.

The warehouse lifting system fetches the load from its storage place and feeds it to the conveyor which carries it to the berth. The goods are then moved from the conveyor with cranes or lift trucks onboard the ship.

4.2.5 Rauma

The paper reel trucks at Rauma port have several technical innovations to ease operation. Some of the truck functions are controlled by a microprocessor; e.g., the computer sees to it that the paper reel is lowered down in an exactly vertical position so that its corners are not damaged (SMV), Other significant features include locking of brakes when the truck has stopped, and the locking of the driver seat in a forward-position in fast driving.

The loading bridge represents another mechanised technique in cargo handling at the port of Rauma. It is used during rush peaks, when the extra loading ramp raises the loading/discharging capacity considerably.

Figure 15. Front-loader truck at Rauma port, equipped with many technical innovations.

4.2.6 Helsinki

The Port of Helsinki is the leading unit traffic port of Finland. It has constantly several ongoing development projects concerning control systems, automation of gate activities, positioning of units and handling gear, etc. Part of the projects has been implemented with promising results. Within the framework of the present study, the Helsinki Port situation has been covered in more detail, e.g. in sections 2.1, 4.2.2, 5.4, 6.2, 7.1, 9.2.2, 9.2.3.2, 9.3.1 and 9.3.2.

5. AUTOMATION IN OVERSEAS PORTS

Automation is used in many overseas hub ports automation to a much greater extent than in Finland. The flows of merchandise passing though these ports are larger in volume and their management calls for advanced control and monitoring. However, the automation of unit handling is still today only partial even in its most sophisticated from. Even in the ports with the highest degree of automation is the world, the loading and discharging operations of the ships and the surface transport vehicles, e.g., are only partly automated. Moreover, units containing dangerous substances or requiring temperature control as well as units forwarded for customs inspection almost always need to be handled manually. Some of the systems in use are described in the following.

5.1 Rotterdam

Rotterdam harbour is the most automated container port in the world. It has, e.g., a system of 56 + 60 AGVs for the transfer of containers between the berth and storage area. The driving speed is 3.5 m/s and the positioning accuracy ± 30 mm. The AGV moves both forwards and backwards. In addition, the port has 24 gantry cranes (RTG) in its automated warehouse and 8 container cranes in the quay area, of which 4 can lift 2 containers simultaneously. The system is located at the Maasvlaketen DSL-terminal (Demag/Gottwald). The terminal capacity is 550 000 containers per year, i.e., some 70 carriers per week. A sum equivalent to FIM 5 billion is reserved for expansion works of the various terminals and for development of the processes.

Upon arrival at the Rotterdam Bell-Line terminal, the trucks report to the administration and receive a smart card with which the truck can access the gantry crane either to deliver or receive a container. A similar application of smart card technology is being used at Felixstowe port. The transport agency is able to print the number and position of the container to be picked up beforehand at its own offices. The automatic device reads the card at the gate of the port, and prints the exact position of the container on it. The driver then drives the truck to the storage area and feeds the card to the scanner, which transfers the data to the warehouse crane. The crane fetches the container and loads it on the truck. The same card acts as the permit to exit the port area.

5.2. Singapore

A Mitsui AGV system is used at Singapore port for the transfer of containers between the berth and the storage area. In Singapore's Pasir Panjang, a warehouse crane automation system has been developed for 80 cranes, utilising different types of sensors. The cranes are operated with remote control in special situations. Brani Terminal 2 has in use a fully automated container storing system with 2 overhead travelling cranes. The applied technology includes optic identification and ultrasonic distance measuring.

5.3 Thamesport

Thamesport has a positioning system for trailers underneath the berth crane, which expedites the picking up/releasing of the container. The automation of the container warehouse has been implemented using wide-gauged container cranes. The traffic between the store area and berths is carried out with AGVs.

5.4 Crane Techniques and Control Systems

Different types of AGV systems and improvement of crane techniques are an important development target in the overseas hub ports. The operation of the AGV was described in more detail in Section 5.1.6.

The German company Noell has developed several concepts for the development of port technology. The straddle carriers in Bremenhafen, Hamburg and Bremen, as well as the rubber-tyred grantries in Algeciras and Singapore, apply automatic spreader gripping techniques created by Noell. The company has also developed an operation-monitoring system for the cranes and, together with ICRAS and Demag, an automatic sway control for the crane load. Other Noell innovations related to port machinery include the energy saving achieved by recycling energy into the network when the crane slows down or brakes, as well as the orientation system for straddle carriers which is in use at three Swedish ports. The development of a control system for 70 straddle carriers using laser technology is currently under way in Hamburg. The NDC company from Gothenburg will probably be in charge of the control system.

Difficulties during lifting and lowering of the load in conventional LoLo handling are due to uneven weight distribution and external factors, such as wind. In addition, the fast and accurate positioning of the gripping device in container handling may sometimes be time-consuming. The microprocess-controlled coupling connecting the crane cable and the gripping device provides a solution to these problems. The most interesting factors in the concept are the sensors of the gripping device and joint, which measure the swaying movement and accelerations. The necessary corrections are made automatically according to the received information.

Thanks to this equipment the handled unit stays automatically in the correct position. The equipment improves the loading and discharging capacity by up to 20%. The benefits are most apparent whenever units have to be placed very close to each other in the holds: the position of the gripping device is always the same when approaching the target surface, and no time is lost in adjustments. Neither does the professional skill of the crane driver play as important a role as before.

The automatic operation control systems (such as Cosmos, used e.g. by Finnsteve of Helsinki; CITOS, used e.g. by Singapore) which automate the port gate traffic, storage, stowage planning of ships, loading and discharging, are in use already at several ports around the world.

An example of computer systems outside the port environment is the system used by Munich airport, which registers the trucks as they drive in and guides them to the appropriate position for loading or unloading. Correspondingly, the crane operators receive an order from the computer to serve the trucks in order to minimise their waiting time.

Figure 16. Rotterdam: the most automated container port in the world.

6. INDUSTRIAL TECHNOLOGY ADAPTABLE FOR PORT OPERATIONS

6.1 Storage Types and Their Internal Transport Systems

Manufacturing plants utilise various systems designed for storage and short transport distances. The scale of the system is often considerably smaller than in the port environment, but as shown below, the basic concepts can be adapted also to port conditions.

6.1.1 High-bay Storage

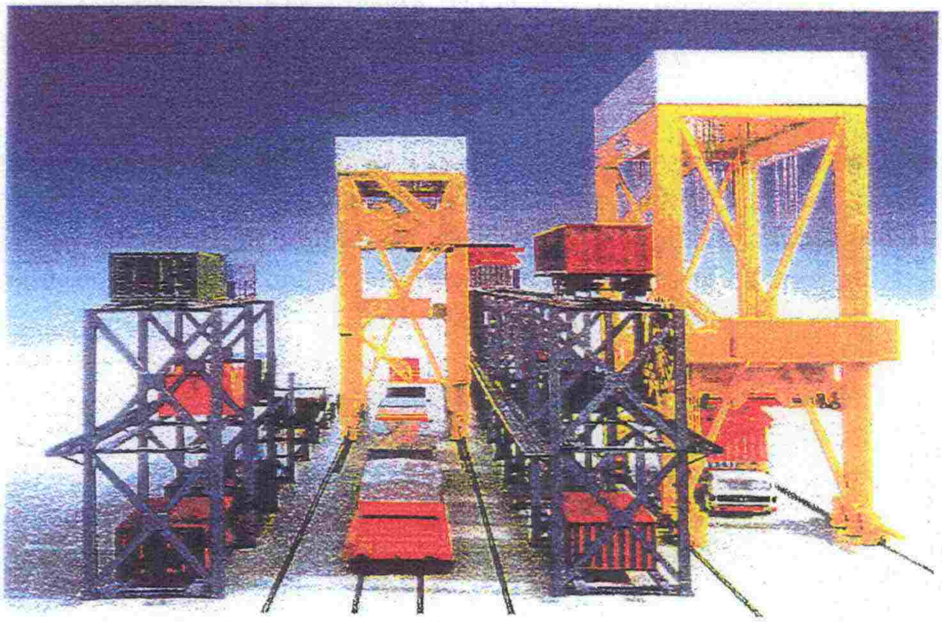
In high-bay stores the materials handling device is a shelf elevator which moves in a narrow aisle. The elevator stores the merchandise on shelves on both sides of the rails. The height of the shelves can be up to 40 m. The storage may have several elevators, each in its own aisle.

Steel reels (30 tons) are an example of the heaviest materials stored with this system, e.g., in Outokumpu Polarit Oy, in Tornio, Finland. An air freight container system is operated with the same technology in London.

The German Noell has offered a solution for intermodal terminals for rail and road container traffic. The system can store containers in two rows on both sides of the rails, e.g. 5 containers stacked on top of each other on the shelf; thus, its storing capacity is normally not sufficient for port operations. On the other hand, the system has a high performance capacity. One device would be able to move some 30 containers/h in or out of the store. The basic principle of the system is that trains and trucks can drive straight into the high-bay store. The shelves have been arranged in such a way that separate aisles have been reserved for trucks and trains between the shelves. One or, if necessary, more straddle-type handling devices move between each lane. To ensure flexible handling, the terminal should be as long as the train. Each unit on the shelves may be fetched individually, without having to move the adjacent containers.

Another advantage is the separation of the loading/unloading processes of trucks and trains. All aisles may be operated simultaneously without affecting the functions of the others.

Figure 17. Noell's suggestion for future utilisation of high-bay stores in intermodal terminals



6.1.2 Flow-through Stores

In flow-through systems the operation is similar as in automatic high-bay stores, with the difference that loads are fed from one end of the storage and taken out from the other (first-in/first-out). The aisles may have several, even 10, loads in a row. The movement of the merchandise through the store is gravity-operated, or motorised with storage platforms on a conveyor along which the load slides. Alternatively the load can be on a wheeled vehicle.

The containers should be stored on shelves and moved through the shelves from one end to the other. This model hardly offers any feasible implementation alternatives.

6.1.3 Satellite Storing

In this type of storing, several loads are placed one behind the other on a shelf. The shelf elevator reaches them by means of a satellite wagon driven into the shelf, which fetches the merchandise even from deep within the shelf to the elevator. Although this technology differs from flow-through storage, it allows equally deep shelf storage. Satellite storing works on the first-in/last-out principle, in contrast to the first-in/first-out principle of the flow-through store.

Similarly as in flow-through storage, the containers should be stored on shelves. The cost per shelf position may rise up to tens of thousands of FIM; e.g. a shelf of 100 containers would cost several million FIM.

6.1.4 Storage without Separate Shelf Elevators (Activ)

The operation principle of the Finnish Activ-system is based on the storing of pallets in long storage aisles; there may be dozens of parallel rows and several on top of each other. Each aisle has its own cable-drawn storage wagons, which can move under the stored loads. The aisle always functions according to the first-in/first-out principle. A transverse vehicle carries the load to the end of the aisle, from where another wagon picks it up and carries it to the storage aisle.

Correspondingly, loads are removed from the storage so that the aisle wagon fetches the load and brings it to the exit end of the aisle, where the transverse vehicle picks it up. Once the pallet has been removed from the end of the line, the wagon shifts all the pallets one step forward towards the exit, in accordance with the control system. If the store-room has several floors, the loads are moved between floors with elevators.

The present Activ-systems function with a maximum load of 1 ton. Probably the only economically feasible alternative is as a one-floor structure, in which containers lie on the floor on rails and a cable-driven wagon runs between the rails underneath the containers. The necessary storing capacity is obtained by arranging an adequate aisle length and number of parallel aisles. The system operates in practice only according to the first-in/first out principle.

Snow, ice and dirt may cause problems in this system, and therefore, a straddle carrier moving above the containers on rails would be a better solution. As the straddle carrier is already in routine use in the container warehouses in ports, even partly automated, this development design may not give many new ideas for the port environment.

6.1.5 Hower Wagons

Hower wagons have been implemented also as automatic guided vehicles and they can move loads weighing tens of tonnes. They require compressed air from a hose or from a compressor of their own.

The hower vehicle is hardly an interesting alternative for replacing the lift truck in ports, since there are sufficiently robust combustion engine lift trucks available. Due to the dusting effect, the hower vehicle is not a convenient alternative in outdoor storage areas.

6.1.6 Automatic Guided Vehicles (AGV)

Automatic guided vehicles have been in industrial use for 30 years. The control system of the AGV enables it to move without rail-guidance, and it is equipped with safety devices against collisions. The AGV is slow (approx. 1 m/s) and generally carries one load at a time. Therefore, it is normally used with low material flows to transfer goods for long-distance transport. Correspondingly, with a higher flow of materials, a larger number of AGVs are needed, as well as traffic control with “traffic lights” and determination of driving priorities.

A conveyor or gripping device can be attached to the AGV for picking up/releasing the load, or the load can be lifted on/off it with an external device. The AGV can also tow a trailer.

During the 1990s, AGV systems have been implemented in the ports of Rotterdam and Singapore. In Rotterdam there are over 100 diesel AGVs in use.

Figure 18. AGV at the ETC-terminal of Rotterdam.

6.1.7 Rail-mounted Vehicles

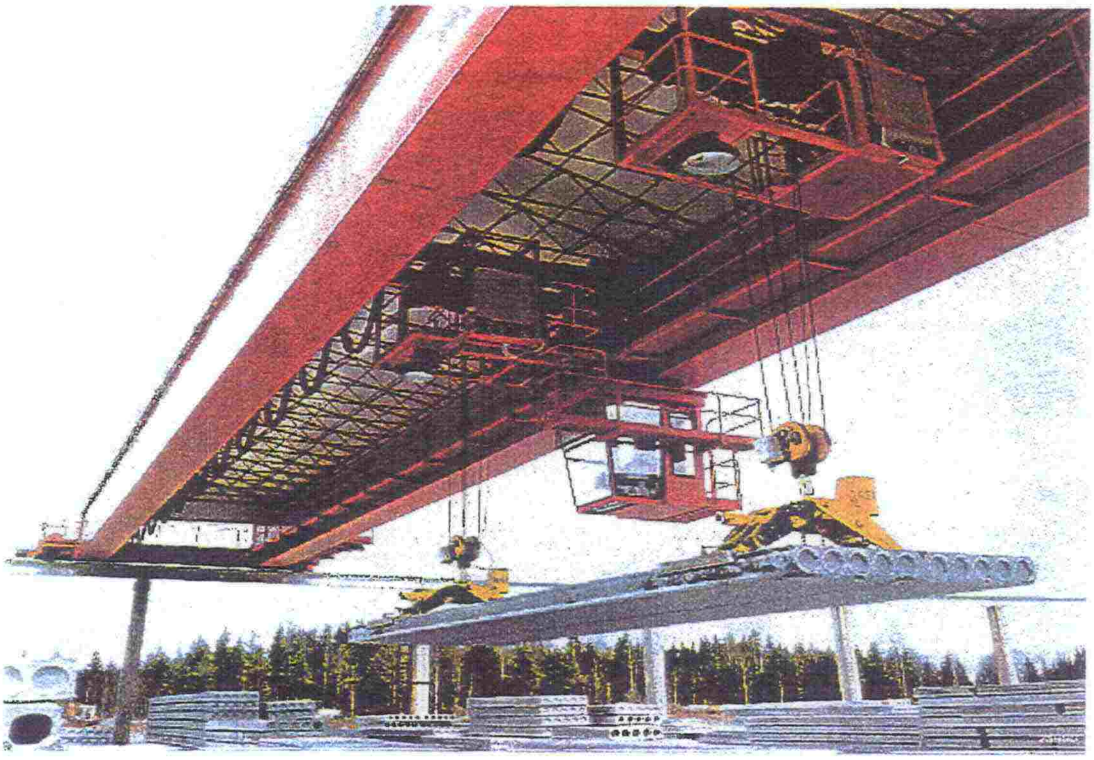
The operation principle of the rail-mounted vehicle is the same as for the AGV, with the exception that it runs on rails and normally in a restricted area where the driving speed may be, e.g., 2 m/s.

An automated rail-mounted vehicle of straddle carrier type, capable of moving transversely from one container row to another, might in some cases be a convenient solution for container storing.

6.1.8 Overhead Travelling / Gantry Cranes

There are both manual and automated overhead travelling and gantry cranes in use. The automated equipment can drive along the rail directly to their destination and pick up/release their load. The systems may have, e.g., 2 cranes running on the same rail, capable of distributing the work optimally between each other and give way to each other. Overhead travelling cranes are used, e.g., in Singapore as automated storing machines. Previously overhead travelling cranes were used in Finland for loading sawn timber from the warehouse directly onboard the ship.

Figure 19. Example of an overhead travelling crane.



6.1.9 Construction Cranes

Construction cranes are also suitable for the storing of empty containers. The cranes can transfer objects within a 40-m radius, but the load grows the smaller towards the outer reach of the radius. Close to the high-bay the load can be 10 tons, but at the peak of the horizontal jib 2-6 tons, depending on how robust the crane is. Since empty 20 ft. containers weigh 2.2 tons and empty 40 ft. containers 3.2 tons, a normal construction crane can handle them within a radius of 40 m, covering an area of almost 5000 m^2. More than 1500 containers can be stored in an area of this size.

This is a good and inexpensive idea, which is already used for the storing of empty containers in Asia, e.g. in Hong Kong.

6.1.10 Monorail

In the monorail system, the load is transferred from one place to another along a rail located in the ceiling. Occasionally, these are multi-branched systems such as the applications in automobile factories. They are also used as buffers in production processes. The support hooks are chain-drawn, or each hook is equipped with its own drive.

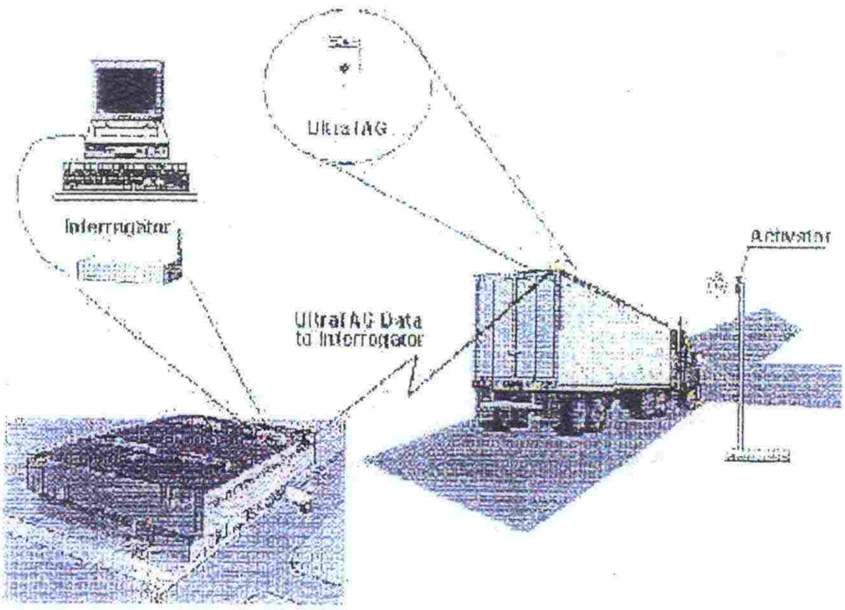
The Germans have also constructed an application for container transport (CONCAR). An example of this application is illustrated in Figure 26.

6.2 Automatic Identification and Computer Systems

Cargo handling consists of two parts: the technique and its control system. Automation cannot be utilised without a functional control system. The benefits of storage and port handling automation remain quite modest, unless the data processing and information flow within the port and the interest groups are developed parallelly.

There are three methods for the identification of persons, equipment and goods: transponders, bar codes and visual identification. The following illustration shows a wireless merchandise identification system, which can identify and follow the movements of pallets, trailers, containers, lift trucks and other large objects.

Figure 20. Ultra TAG: a wireless merchandise identification system.



The Ultra TAG system, manufactured by Randtec Inc., USA, is packed into a UV-protected ABS plastic. It emits radio signals for the identification of the merchandise. Ultra TAG activates itself at the check point, which can be located, e.g., at the port gate or berth area. The scanner of the emitted radio code can be connected to the data base that controls the storage system.

The transponder systems represent a promising application of technology, but their problem is the lack of standardisation. The equipment of one manufacturer does not read the transponders of the others. ISO 10374 gives only a partial solution to the problem. The transponder system is also a costly investment (à FIM 20).
Bar codes are an inexpensive marking method. They are also well standardised and therefore not manufacturer-dependent. There are also bar codes that can be scanned from a distance of over 5 m. The development of the bar code or identification chip is a continuous process in all ports. Finding a functional alternative for winter conditions would expedite the adoption of other automation. The identification and registration of a product into the data system is a basic condition for the creation of integrated control systems, and thereby also for increased automation.

The visual identification of numbers is a new method requiring the use of a camera and related software. The reading accuracy with the present technique is about 90%. Maher Terminals, USA, for instance, aims at completely paperless electronic data interchange (EDI) with all interest groups by means of a visual identification system at the port gate and a computerised warehouse management system.

The computerised systems for container handling and storage are very advanced. Some companies such as Finnsteve, Helsinki, apply a satellite system for the monitoring of straddle carriers. Spreader operations are controlled to the extent that each change in the warehouse position of the container may be followed: real inventory control. Also at the Hietanen port of Kotka, a satellite system is used for container positioning. The system, developed by the Finnish company Modulaire Oy, positions the containers and handling machinery with sophisticated GPS technology using the so-called double-frequency system, which allows a positioning accuracy of up to 2 cm.

The container straddle carriers at Hietanen port are equipped with a GPS sensor. The GPS system relies on American satellites. In case of a shadow area, the connection failures are corrected by the straddle carriers' multi-sensor technique, e.g. by the fibre-optic gyroscope. The number of the container to be found is fed into the data system, which forwards it straight to the straddle carrier. The driver sees all the necessary information on the PC monitor screen in the driver's cabin. The system defines the area, row and square where the container is to be found. Satellite-controlled positioning sensors guide the straddle carrier to the correct place, regardless of possible snow and ice.

Singapore port has gone still further. The effort to control a major part of the transport chain and improve productivity has motivated the Port of Singapore Authority (PSA) and the National Computer Board (NCB) to join forces. The monitoring of containers has been extended outside the container freight station, e.g., to automated monitoring of road transports. This kind of cooperation between the various parties in the transport chain has resulted in improved productivity and resource management.

In Finland, the efforts to achieve rapid and real-time information transfer between the port and its interest groups stimulated a new project in 1992, called Portnet. Portnet is a data service network operating in Finland for ports and maritime traffic, based on the flow of electronic information updated in a central data bank. Enquiries or data transfers to the organisation's own computers can be made from the database of the central computer, e.g., in the form of EDIFACT (EDI) messages. Through Portnet, the ports and other interested parties (Portnet users) receive up-to-date information on arrivals and departures of ships, their loads and load rotations, etc. This eases resource management and production planning of all parties involved.

7. RESEARCH AND DEVELOPMENT OF CARGO HANDLING AUTOMATION SYSTEMS

7.1 R&D of Port Cargo Handling in Finland

To date, the most comprehensive Finnish study on cargo handling has dealt with chemical wood industry products. Its findings are compiled in a series of publications prepared by TEKES (Technology Development Centre), entitled "Paper handling and transport 2000" (PKK 2000). One important integrated programme is the R&D programme on the transport chain and its links (KETJU), implemented with financial support from the Ministry of

Transport and Communications (MTC) and TEKES. Another important project initiated by the MTC in 1998 is the Research and Development Programme for Traffic Telematic Structures 1997-2000 (TETRA).

A brief description of previous and on-going development projects in the field of port cargo handling follows. Finnish research has especially been focused on the automated unloading of paper reels from trucks/trains, involving the construction of, e.g., pilot equipment in the ports of Kotka and Hamina (Paper 2000).

The manipulator constructed within the framework of the TULKO project is based on a payloader equipped with a paper reel gripping device and optical sensors. It can find a rail wagon, the door of the wagon and the reel, and grip it. The further development of the prototype has been discontinued for the time being.

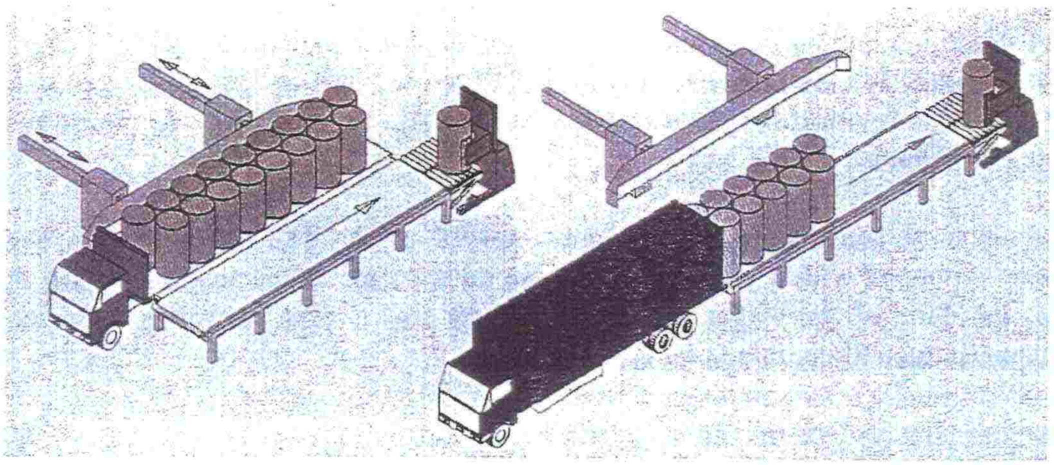
The Hamina port equipment consists of truck cargo unloading equipment and an AGV carrying the reels to the warehouse. The weight of a reel is 3 tons. The truck is unloaded by pushing the reels simultaneously to the warehouse. This requires that the truck's platform is steel-plated. The reels on the berth settle on the conveyor 2 reels side by side. At the end of the conveyor the AGV picks them up, takes them to the warehouse, finds a vacant position or an incomplete stack, and releases the reel. The equipment is not yet in operative use.

One alternative for unloading a truck, which is already in use, is equipping the truck with a conveyor which enables unloading from the rear end of the cargo space.

The port of Hamina is also using another advanced method, in which the paper reels are loaded on a flat in the warehouse. The flat is taken to the berth alongside the vessel with a lift truck. The paper reels are still mainly loaded with slings, but loading flats have been taken into use to reduce the risk of damage to the goods.

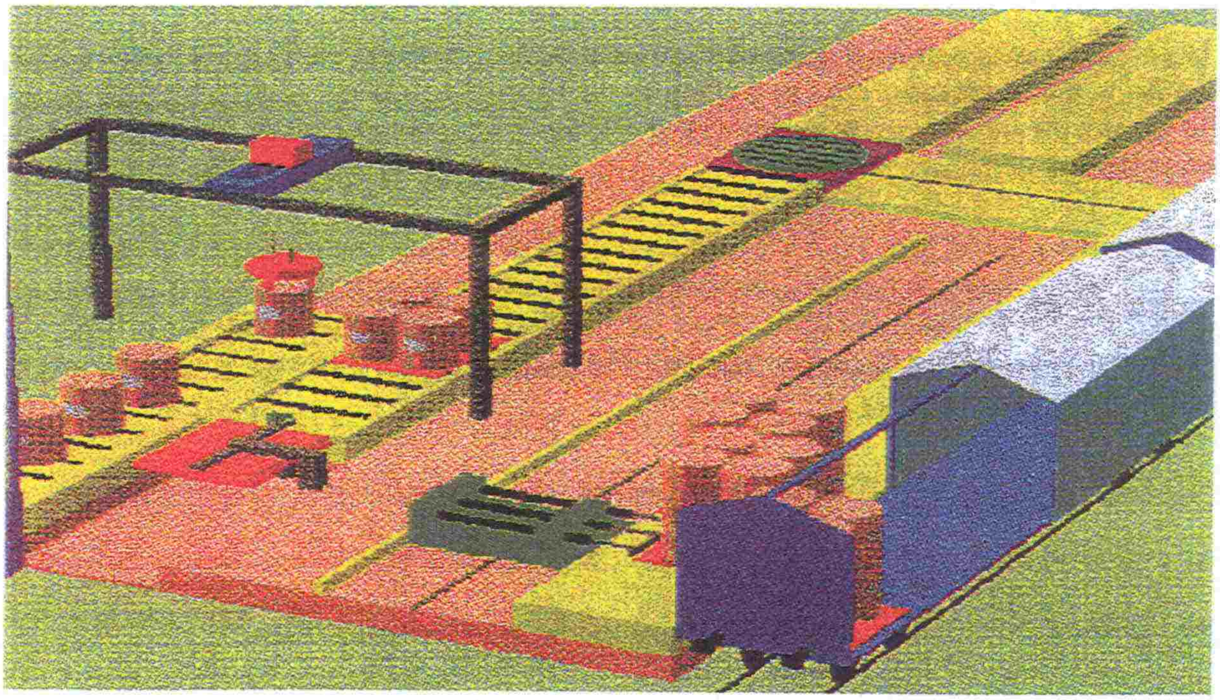
There are two sizes of flats: the 4 x 2 m flat carries about 12 tons, and the 6 x 2.5 m flat (20-ft. flat size) carries about 20 tons. The crane is equipped with a lifting frame, which is lowered on top of the flat and locked into place. Once the flat is onboard, another empty flat is lifted off board. This application is important especially in handling several different-sized reels, which are difficult to lift with slings.

Figure 21. Paper reel unloading in the port of Hamina (VTT, Permala)



The utilisation of thin, 3x3 m board (e.g., veneer) has also been suggested for paper reel handling in Finland (VTT). The reels would be placed on the board and the whole unit moved from one mode of transport to another. There is, however, no possibility of lifting in this alternative.

Figure 22. Schematic view of light-weight flats used in rail wagon loading (VTT, Permala)



The difference in comparison to cassettes is that the flat does not weigh much, and it need not be returned. Its disadvantage, naturally, is that it cannot be moved without the help of conveyors or the support of other cargo, and it cannot be lifted.

The most recent development in the automation of paper reel handling is the rail wagon loading system created by Pesmel Oy. The system enables loading of the whole wagon in just a few minutes, and can be used for unloading as well.

Apart from development and automation of paper reel handling, not much R&D work has been carried out for the automation of other sectors of cargo handling. Some of the known cases are presented below:

- In Helsinki, Finnsteve has developed the satellite monitoring of straddle carriers for the automatic transfer of container storage information. Monitoring the straddle carrier and also the spreader movements with the satellite positioning system makes it possible to determine the container positions. At the same time, it enables automation of storage inventory. The target positioning accuracy is 1 m.

- In the EU as well as in Finland there are some ongoing projects for the development of automatic identification of the container code number.

7.2 Port Cargo Handling R&D in Other Countries

Elsewhere in the world, the great volumes of the cargo flow-through at the ports and the scarce or expensive land have forced countries to invest more time and money in the cargo handling research and development than is the case in Finland. The big international companies operating in the overseas ports have more resources for the management of development projects. Some of the most important international innovations are presented below.

The German Preussage Noell has been actively developing different kinds of alternatives for the handling systems of container terminals. At the Euro-Kai port of Hamburg there is a linear motor system on rails created by Noell for moving containers between the berth and the storage. There are separate vehicles for moving pallets. A container crane lowers the container to the vehicle, which takes its on rails to the corresponding storage area. The vehicles are guided automatically, and the storage position of each container is entered into the terminal control system. In order to ensure a high level of operational reliability, the vehicle itself has no other moving or active parts except the wheels. Climatic conditions do not affect the operation of the system, because the vehicles are moved with powerful electromagnets. The vehicles move on a gridded frame of rails, which enables 90° turns.

Figure 23. Noell's linear motor system.

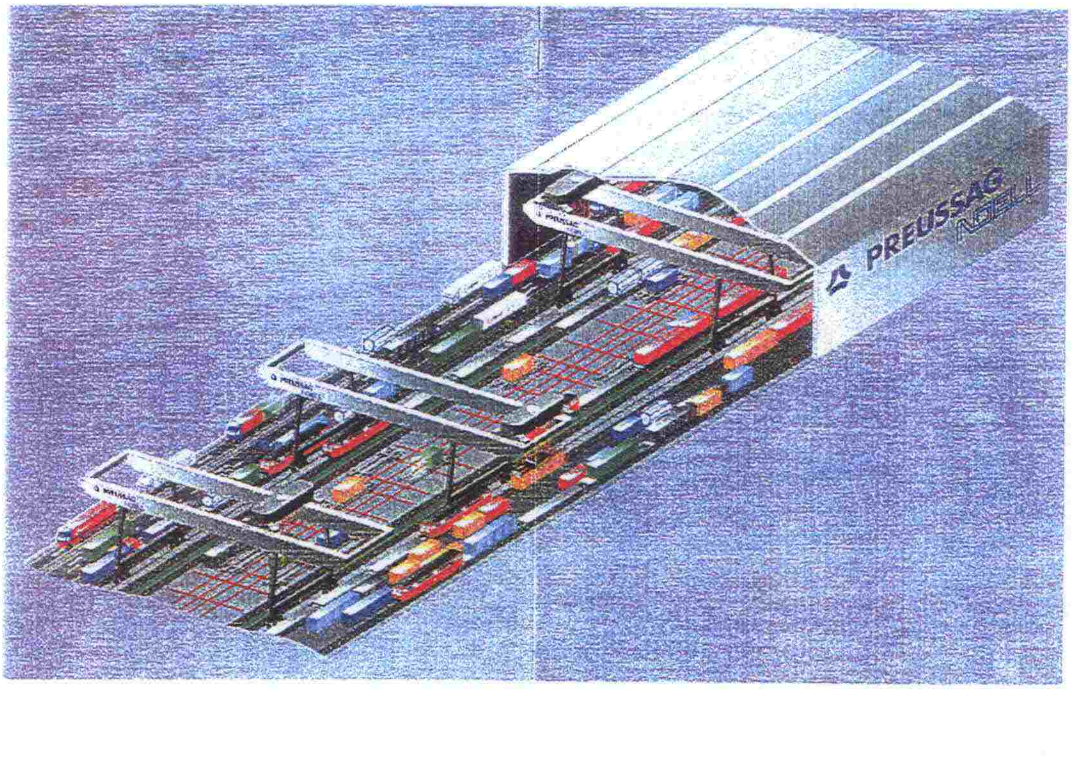
According to study findings, the costs of the linear motor system per cargo unit have proved to be up to 10% lower than those of other container handling systems. Noell's innovation, however, sets additional demands for the loading/discharging techniques used (container cranes). The speed of the present container cranes is not sufficient, which may cause congestions on the berth.

Another concept developed by Noell is the so-called Mega-Hub system, where gantry cranes and flats are used for moving containers between trains or trains and trucks. The system consists of 10 cranes and several conveyors for longitudinal transfer carried out with 5 rail-mounted gantries (RMG).

There are several prerequisites and assumptions related to the design and start-up of the Mega-Hub system, which is currently under construction in Germany (Hamburg). The handling capacity should be at least 500 000 transfers per year, which means more than 1300 per day. At the same time, the storage requirement is relatively small, an average of 270 units at a time. The time-sharing of using the terminal is arranged so that transfers from one train to another occur mainly during the night and, correspondingly, from rail wagons to trucks during the daytime.

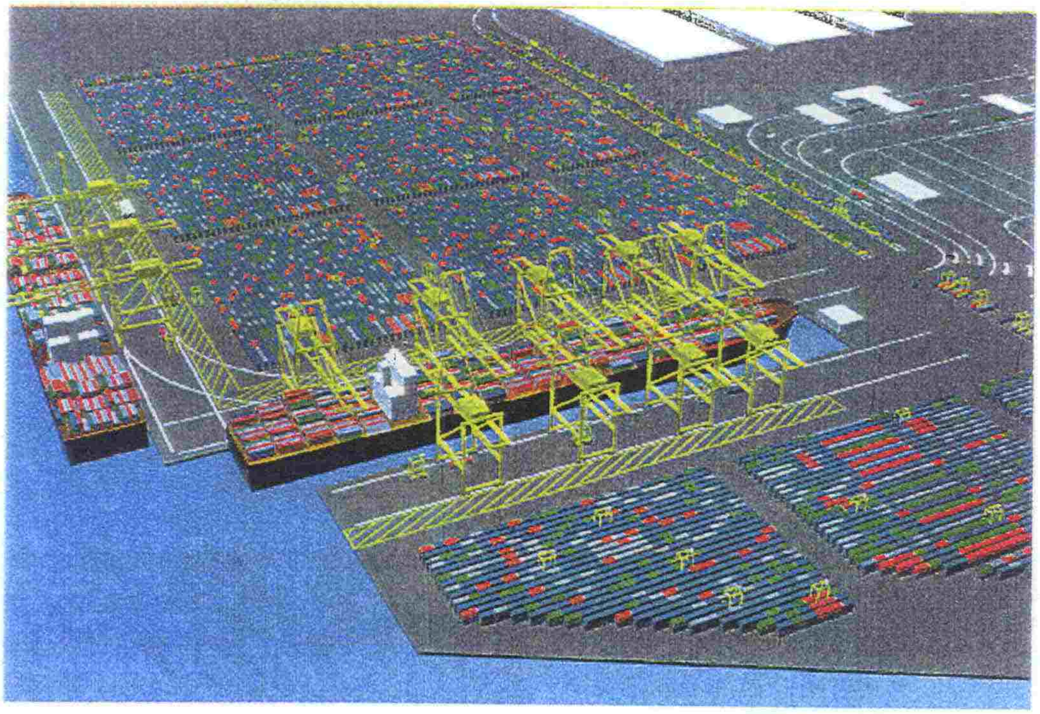
The exact positions of all units in the terminal area are controlled in real-time, and practically every unit can be reached without moving the other containers. This, together with sophisticated automation, enables high handling speeds, reliable operation and small manpower requirement. The Mega-Hub system has been largely implemented on the basis of techniques which are already in use. Further cost savings are incurred by small space and energy requirements and low maintenance costs. Figure 24 shows an application of the Mega-Hub concept.

Figure 24. Mega-Hub concept designed by Noell



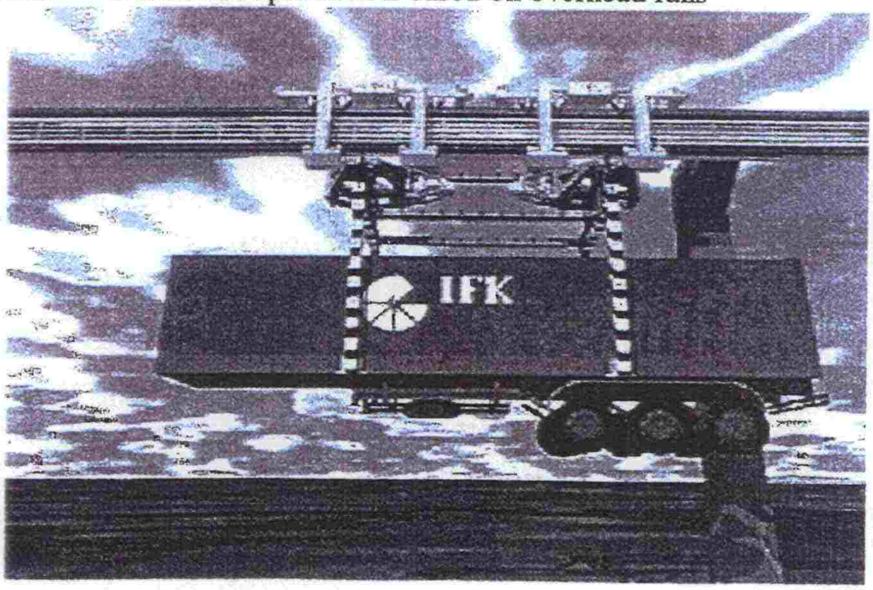
There are several terminal systems being developed to expedite the loading and discharging operations of container carriers. An example of an unconventional design is the container terminal which will probably be constructed at Amsterdam port. The concept, which has already been under development for a number of years, is based on the idea that there are gantry cranes operating on both sides of the vessel. Berthing the carrier in an enclosed basin, protected from the roll of the sea, enables the operation. The cranes are designed to be mobile so that there may be 1-6 cranes on one side, depending on the need. The maximum number of cranes working on one vessel is 10, adding up to about 300 lifts per hour.

Figure 25. Cargo handling on both sides of the vessel



In Germany, Thyssen together with the University of Karlsruhe is developing a container exchange and transport system called CONCAR (train-train/train-truck), based on overhead rails. Figure 26 shows a model of the operation of the CONCAR system.

Figure 26. CONCAR operation is based on overhead rails



A Combi-Road system is being developed in Holland (Rotterdam, Terberg Benschop) for the transport of containers from the port to an inland terminal. The goal is to reduce road congestions. The equipment consists of an automated electric tractor without driver and a semi-trailer, moving on special rails at 50 km/h. The aim is an unmanned combination driving alongside other traffic. But, this still requires more developed obstacle sensors and control systems. The concept has been in test use since 1995 and the results are promising.

Figure 27. Combi-Road

The EU Commission often participates in projects which aim at improving the competitiveness of European ports, either as the client or financier of the project. The following is a brief summary of the EU projects related to the development of automation and mechanisation in European ports.

- CONTROL-C: The objective of the project is to enhance the efficiency of container handling equipment by applying new techniques to the present systems. This includes the development of straddle carrier automation by improving the quality of data connection between the equipment and the store management unit of the container station.

- IMPREND is a project for the development of the initial and final transfers in the terminals. The objective is to analyse current initial and final transfers and to make suggestions for improving them all over Europe.

- IMPULSE is a project to develop intermodal operation techniques especially on railways. The objective is to present technical and logistic alternatives for the improvement of the profitability, management and technical efficiency of intermodal traffic.

- INTERPORT aims at finding and testing automated identification systems to facilitate the identification and monitoring of transport vehicles, containers and cargo handling equipment in the ports. The goal is to find a functional concept for automated identification, which transmits real-time information through EDI on individual transport vehicles or containers (MTC, Setec Oy, and Viatek Oy of Tampere, Finland)

- PRECISE IT aims at optimising the operations of intermodal terminals. The automated positioning of cargo handling equipment and stored merchandise at the terminals simplifies warehouse management and appropriate dimensioning of the resources.

- TACTICS is a new project, which studies the possibilities for automated materials handling in intermodal operations.

- TERMINET aims at finding new handling alternatives to meet various terminal needs. The objective is to achieve a better price-quality ratio in all European transports by developing new, innovative cargo handling systems based on automation and robots. (MTC, VTT).

7.3 Research and Development of Cargo Handling in Vessels

The vessels themselves are probably the least know area in the seafreight chain. A lot of research has been conducted in this field, but still it never receives much attention. From the shipowner's point of view, the ship represents an asset, and it is therefore important to maximise the volume of transported cargo per time unit in order to ensure the efficient use of the invested capital. Shipowners have attempted to increase their freight income and to improve profitability by investing in larger vessels. But to achieve this, efforts must first be made to shorten the turnaround time at port before increasing the ship size. On this point the shipowner has only indirect influence, unless the owner decides to include port operations as a part of its own activities.

The ship is one of the links in the transport chain. The mechanisation of cargo handling together with the unitisation of cargoes has considerably changed cargo handling onboard the vessels and made it more efficient. A brief description of the methods currently used in carrier cargo handling and related innovations follows. Annex 1 gives more detailed information on the automation of onboard cargo handling in Finland.

The same general principles and goals concerning the automation and mechanisation of cargo handling that apply to port and terminal operations also apply onboard. Nevertheless, the ship environment introduces some additional goals and limitations as compared to cargo handling methods and unit sizes at port.

The technology for loading and discharging of cellular container carriers is already being applied in deepsea traffic. The focus in this context is therefore on LoLo and RoRo applications, which are very important in Finland. Several concepts have been already been developed that would shorten the turnaround time of vessels and reduce the manpower needs. The problem is their cost-efficient implementation.

The efforts to automate cargo handling onboard can roughly be divided into two groups: 1) loading/discharging operations and 2) automation of cargo securing. Several factors affect the development and implementation of new innovations. Some of the limitations and prerequisites include:

- Individual demands and characteristics of the transported goods.
- High investment costs and long pay-back periods.
- Efficient application of specialised systems to different transport units.
- Lack of commitment of the parties in the transport chain; authorities, other transport modes, etc.
- Need to achieve internationally feasible and functional, uniform systems.

The full utilisation of the new concepts requires high frequency and large volumes in line traffic. The automation of onboard cargo handling sets its own demands on the supra-structure of the port area: the terminal has to be capable of loading and discharging the vessel at the expected capacity, otherwise there is no benefit to be gained. The development of the ships' cargo handling must therefore be based on simple and flexible alternatives, such as:

- Automatic or semi-automatic cargo fastening/unfastening system.
- Design of holds: unhampered, simple, uniform.
- Larger cargo units, increased number of units handled at a time.
- Possibility to transport several different intermodal units: units, ISO-containers, trailers, other conventional cargo units.
- Possibility to operate more efficiently in the holds, e.g., by using 2 double ramps, 1 for each deck.

The purpose of IPSI, a research project initiated in 1996 and financed by the EU, is to examine and develop the interface between ports and vessels in multi-modal transportation. The motive of the project is to increase the competitiveness of waterborne traffic as a part of the transport chain, and new technical solutions are in a key position in this respect. The Kvaerner Group has the main responsibility for project implementation. The conclusions of the project will be published in spring 1999.

7.4 Onboard Innovations

In the LoLo system, the load is lifted with a crane - either the ship's own gear, or the berth or mobile cranes - vertically on/off board the carrier. The crane can be equipped with different types of gripping devices, depending on the cargo. Traditionally the cargo space consists of one or more holds with hatches (von Bagh 1988). Table 1 presents innovations in LoLo handling.

Table 1.

CONCEPT NAME	MANU-FACTURER/ DESIGN	YEAR	APPLICATION/ OPERATION PRINCIPLE	INFORMATION ON USE
Loading boom structure on the on the vessel	Valmet Oy	1972	Load cannot wind around its vertical axle	Not available
Dock Express	Kone Oy		Cranes move on rails mounted on the sides of the vessel	Delivered to a Dutch dock-type vessel.
Gantry crane application onboard ship (concept)	KCI Kone cranes, Kvaerner Masa-Yards		Crane is based on a standard product and might include an automatic positioning system	Under development
BIW Feeder (concept); smaller, fast container carrier			Bridge-type cranes, same width as the holds, and mechanism, for moving of containers	Not available
Twinstar (concept)	Immo-R. and Raimo-R. Nordsröm		Automated warehousing adapted to a ship's environment (for container carriers)	Not available
Gigaideas gantry crane (concept)			Gantry-type crane installed above cellular holds of ship	Not available
Ship and its loading/ discharging systems (concept)	Jaakko Pöyry Oy	1987	Side-door vessel and bridge cranes for unit cargoes	Not available
Ship and its loading/ discharging systems (concept)	Jaakko Pöyry Oy	1990	Side-door vessel and bridge cranes for unit cargoes	Not available
System for positioning of the ship and the onboard crane for loading the vessel (concept)	MacGregor-Navire (FIN) Oy	1994	Cargo positioning with signal transmitter and receiver	Not available
Unit cargo carrier (concept)	Pekka Rapeli	1996	Cargo vessel for transport of wheeled vehicles, containers and palletised goods, with side door and cargo handling equipment in holds	Not available

In RoRo handling the cargo is taken onboard on wheels either through the aft, stern or side ramps. The transfer takes place with the load in a horizontal position. The units are large-scale units and their handling is fast. The system is suitable for different types of cargoes. Table 2 summarises the innovations in RoRo handling.

Table 2.

CONCEPT NAME	MANU-FACTURER/ DESIGN	YEAR	APPLICATION/ OPERATION PRINCIPLE	INFORMATION ON USE
"Scandic"			Aft-ramp carrier; containers are placed transversely in the holds. The lower hold is stowed automatically with conveyors.	Originally in use in Sweden., and in Finland by Bore Lines. Still in use in one form or another.
Finnflow system			System applies jumbo platforms, which are transferred onboard the ship and moved with a cable-drawn wagon to the position in the stowage plan.	Applied in Finncarrier vessels. First "Finncarrier" in 1969.

Other individual innovations in ship cargo handling as well the ones described above and their corresponding patents are detailed in Annex 1. The above innovations are all relatively old. The following sections describe two, more recent systems.

7.4.1 Automatic Cargo Lashing System

The fastening of RoRo carrier cargoes is a task which demands a great deal of manual work and takes a lot of time, if performed in the conventional way. In spite of effort put into it, the final result is often poor and does not always fulfil the regulations on ensuring safe cargo transport. This year, the Swedish Tor Line is receiving 3 new RoRo carriers with several innovations. One of the most interesting details in them is the securing system for trailers.

A basic factor in the trailer securing system is a trestle which attaches itself to trailer's pull knob, which, in turn, is attached automatically to the ship's deck with 4 twistlocks. The final securing is by means of 2 cross-fastenings to the deck. This reduces manual work considerably, but requires that the trailers have to be positioned on the deck even more accurately according to given instructions. When necessary, the cargo can also been fastened in the traditional way. The new securing system is considered to improve efficiency significantly.

7.4.2 Case Stora - Wagenborg Shipping

The Swedish forest industry group Stora has contracted the Dutch Wagenborg company for the chartering of 14 000-ton carriers for the traffic between Gothenburg and Zeebrugge. The 3 vessels will be taken into use at the end of 1999, and Stora has an option for a fourth one.

As a basis for its system, Stora has developed a new unit type in which the utilised cargo capacity is around 80 tons. The units are loaded already at the plant, so the goods do not require separate storage at port. The unit was developed in cooperation with the Swedish Railways, which takes care of the feed traffic to Gothenburg port. Centralised shipping is carried out from Gothenburg to the distribution centre in Belgium. The in-depth development work and cooperation between the railways and Stora Group is, in fact, essential here.

A new feature in the system is the aft loadable/unloadable RoRo carriers which enable operations on both decks simultaneously, thanks to the double-level system. This also makes it possible to increase automation in loading operations in the future. In addition to Storaboxes, the vessels can also carry other intermodal units and unit cargoes.

When all 3 ships are in use, an estimated 2.5 million tons of Stora products are shipped through Gothenburg port annually. The port's investment into the terminal and berth structures is around USD 20 million. Stora itself is contracting the construction of the necessary terminal arrangements in Zeebruggen. It has calculated yearly savings of SEK 200 million as a result of the new transportation arrangements. The return cargo to Sweden consists mainly of recycled paper as well as pulp for Stora's needs. Understandably this is not enough, so the extra cargo space is marketed and sold to outsiders.

The unsuitability of the Storaboxes for intercontinental connection transports and for inter-European transports hampers their more extensive use. For such transports, the goods have to be unitised again (into containers, etc.) or shipped as unit cargo. In these cases, not all the benefits of intermodal transportation can be fully utilised.

Figure 28. Terminal arrangements in the Stora concept

8. DEVELOPMENT OF NEW METHODS AND SOLUTIONS

8.1 General

The basic structures of the transport chain have evolved decades, even centuries ago, and still remain the same. However, some components of the chain, such as the transfer of information, handling techniques, land and sea transport vehicles, and the organisation of the companies involved, have become more efficient in the course of time.

Whichever party makes an effort to develop the chain, its primary interest and expectation is the benefit it gains for itself. As several customer enquiries have proven, such benefit may be economic, technical, or affecting its image. A requirement shared by all participants in the transport chain is *timely and sufficient information,* handled by the various parties at different levels according to the application and value of this information. The pieces of information needed by the individual parties always forms a part of the total body of information necessary for the management of the transport chain.

8.2 Bottlenecks in the Present Transport Chain

The large central wholesalers which are involved in import operations, as well as the importers of perishable goods, have developed their shipping information and monitoring methods into an important part of their services and marketing functions, although tailored to the needs of their respective systems. In the "Port 2000 Seminar" held in spring 1998, the message of the import companies regarding the development of the transport chain was: "Close collaboration between the port, sea and land transport operators".

As for export goods, the situation is much more complicated at the practical level. The flow of information, and often its absence, between the parties of the transport chain cause problems of identification, delays in operations, errors in shipment or timing and, consequently, extra costs.

The following sections examine the defects as well as the factors which have a great importance in everyday work and whose elimination alone will improve the efficiency and smooth functioning of the transport chain.

8.2.1 Problems in Information Flow

- The content of each intermodal unit entering or departing the port has to correspond to the shipping documents of the unit. In different stages of handling, the identification, registration and estimation of the condition of the intermodal unit are based on camera monitoring and/or visual checking. Therefore, the identification labels and markings have to be clean and they have to be located so that they are in clear view and readily legible.

- Insufficient information between the plant and the port concerning the cargo, its quantity or time of delivery, may cause unnecessary, sometimes even long storage at port or overdimensioned pressures on production. The immediate effects can be seen in the incorrect dimensioning of personnel resources and machinery, which, given the already tight schedules, causes backlogs.

- The slow exchange of information between the financial institutions in different countries, and the differences in national operating patterns between the countries in overseas trade, influence the loading order and the speed of loading and discharging.

- The modification of the customs documents to correspond to EU practices and the differing requirements of the various overseas countries also cause problems. Last-minute stuffings cause delays due to the time it takes to prepare the customs documents.

- The differences in the practices of smaller suppliers (data systems/lists) concerning cargo information to the forwarder, port operator and shipper.

8.2.2 Problems in Cargo Handling and Storage

- The functional layout of a port is the master plan for port utilisation. E.g., unnecessary port traffic can be minimised, and smooth loading and storage ensured by means of appropriate traffic arrangements.

- Guidance of the trucks bringing in and taking out cargo, and clear indicator signs within the port area are necessary for finding the correct loading and unloading places.

- Transport of various consignments in the same land transport vehicle causes internal transfer traffic between different cargo terminals.

- Increasing demands on storage management. As the consignment sizes decrease, the accessibility of the merchandise during stowage is all the more important for smooth operations. Special situations (specific stowage orders for wood materials, e.g. 1/3 on deck, 2/3 in holds) increase the need to create systems enabling the accessibility of each cargo unit at all times.

- Wide-range space requirement of onshore machinery, and characteristics of the merchandise to be stored. The utility height based on the use of a front-loader truck is directly dependent on the cargo amount necessary for the feeder traffic to the vessels. The height increases the need for loading machinery.

8.2.3 Problems in Resource Management

- Working hours of port terminals: The reception of containers or other intermodal units at the port involves the cooperation of several parties. If the working hours at port are extended, the port operator, customs, forwarding, port authorities, shipowner, and shipper would, correspondingly, have to adapt themselves to the new situation. It remains to be studied whether the extension of working hours would stabilise the peaks in truck and railway traffic and whether the utilisation rate of the equipment would grow significantly.

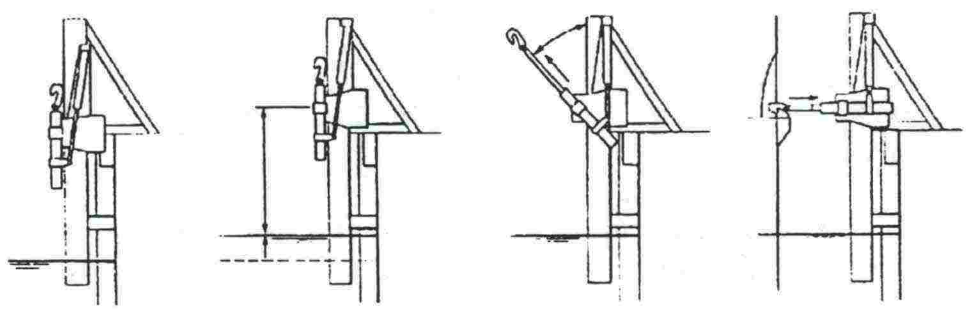
- Adaptation of working hours to the arrival and departure times of RoRo traffic. Between the fast discharge and loading phases, there remains a period of time during which the utilisation of resources is very inefficient; nevertheless, a certain standby status has to be kept to maintain an appropriate service level.

- The late arrival of a unit to the port often means a delay in shipping confirmation. This, in turn, causes changes in the stowage plan and a reduction in overall efficiency.

- Fixed working hours and rigidity of the labour market policy.

- Relatively long mooring time. The aim of all parties is the get the ship out of port within as short a time as possible. The fact that the total time of the ship at port is only a few hours stresses the importance of speedy mooring and unmooring. Figure 29 illustrates an automated system for expediting the mooring and unmooring processes.

Figure 29. The automatic mooring and unmooring concept



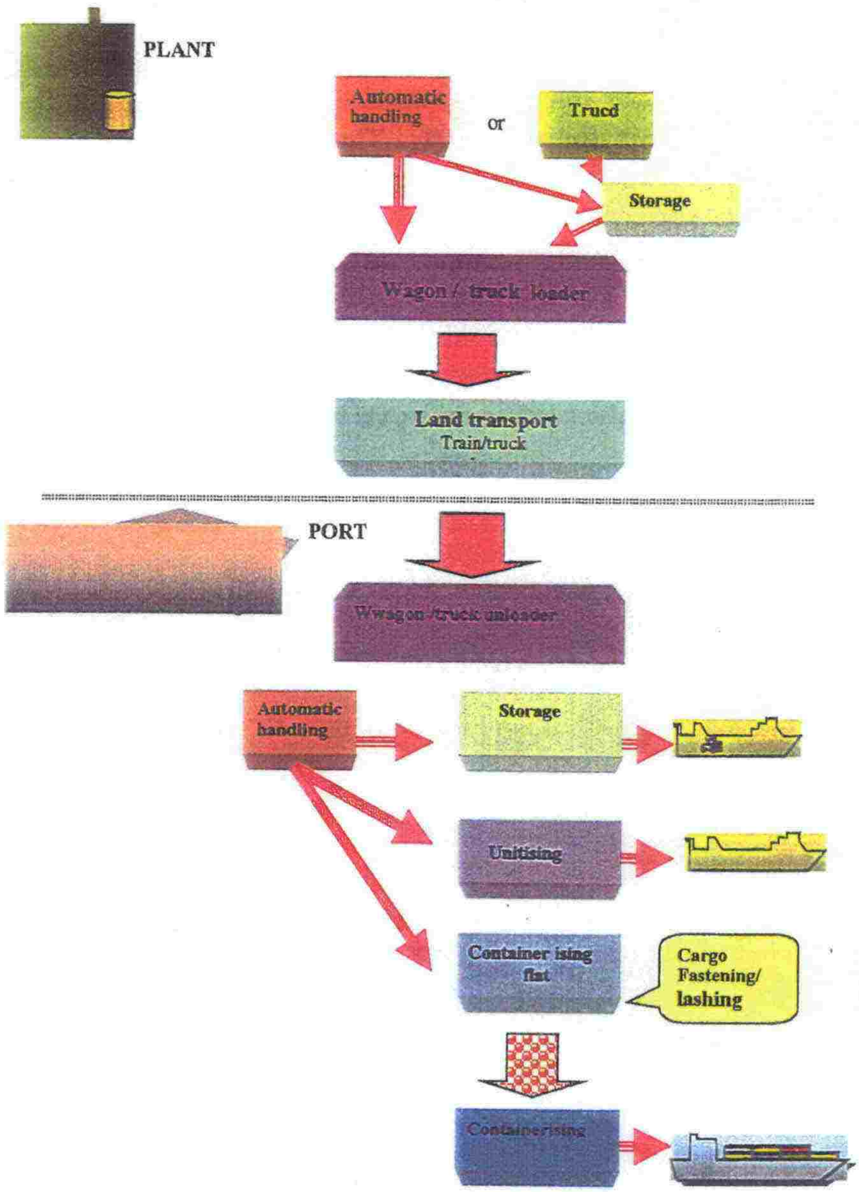
Even though customers are satisfied with the way the present transport chain functions regardless of certain deficiencies, future requirements for better services and minimised damage to the goods call for a higher degree of automation also in the ports. Even slight deviations from the normal are accentuated under the present transportation management systems and the increasing speed and efficiency of cargo handling. Modern techniques, innovative thinking, and collaboration between the parties can help to eliminate or at least reduce many of the bottlenecks and extra cost factors in the transport chain.

8.3 Development of Cargo Handling Automation

The following sections present different possibilities for reducing the problems in the transport chain though automation. In the paper industry, e.g., the development process regarding automated loading and unloading systems has been ongoing for a long time already. Similar cargo handling automation systems could also be utilised in the future for handling other types of cargoes and development of handling systems.

The following diagram describes the merchandise flow in the transport chain from plant to port and onwards. The management of the entire chain calls for cooperation from all parties involved.

Figure 30. Merchandise flow from manufacturing plant to loading onboard



Previous sections have identified the most common bottlenecks in port operations. The application of automation and the mechanisation of cargo handling at port may eliminate, or at least reduce, the pressures for cost increases and the damages caused by human errors, and expand customer services outside the regular working hours.

The following describes at a general level the integrated handling system for forest products. In principle it is divided into three operational groups at port:

- Reception and unloading from the land transport vehicle.
- Unitisation or storage.
- Containerising.

The above operational groups can futher be divided into subcomponents. The operations can also be located elsewhere than at port. Apart from the development of new cargo handling technology, the aim to reduce damage to the goods calls for a reduction in handlings of the goods. Thousands of different types of units are handled daily at port, which naturally increases the possibility of damage. If unitisation can be carried out already at the manufacturing plant, the damages caused by cargo handling may be minimised.

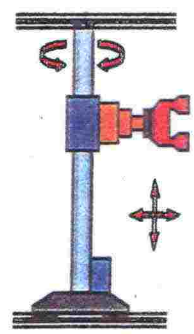
After determining the shipping time, during the transport of the merchandise to the port or during loading or unloading operations, there are numerous outwardly similar units being handled and stored at port simultaneously. The existence of a quick and reliable way of identifying the goods is, therefore, of utmost importance. The sticker tape or identification chip used by the paper industry may already be considered as a partial solution. Reliable identification of the goods is essential for the further development of automation.

Speedy loading and unloading systems have, in fact, developed partly as a result of increased just-on-time/just-in-time (JOT/JIT) transport demands. The development of land transport loading and unloading has advanced to the point where the entire load can be shoved in or out at a time, as shown below.

Figure 31. Mechanical loader/unloader

8.3.1 Automatic Handling Unit

Figure 32.



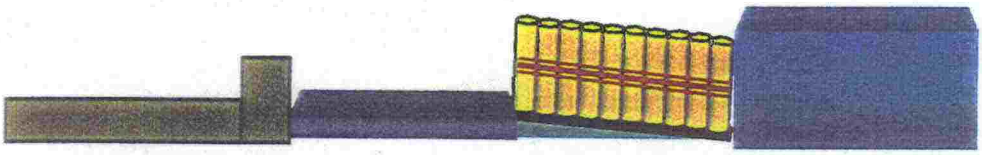
Chemical wood industry products are handled with a front-loader truck equipped with an attachment. The handling system can be further developed by applying an automatic handling unit for storage, unitising and stuffing of container plates. This practice is based on *the application of existing* ***basic technical solutions*** *to the operating principles applied in plants and port warehouses.* The automatic handling unit replaces the conventional lift truck/attachment combination. The handling unit stores and loads units, bolsters and plates for container loading, following the computer software configurations.

The automatic handling unit is most adaptable to warehouses where the tonnage to be handled is large but the storage time is short. Consequently, the layout of the warehouse should be adjusted to the needs of automation, and not vice versa, forcing the automation to fit the existing storage alternatives, as has been the case up till now.

8.3.2 Containerising

Containerising is carried out still today with lift trucks or other devices directly to the container. An alternative is *preloading of the plate designed for containerising*, and shoving it into the container. The container dimensions correspond everywhere to international standards, and therefore preloading and even supporting the goods can be done automatically by means of commands stored in the computer's memory.

Figure 33.



As shown in the above Figure 33, the moving of the plate itself with its load to the container by utilising the favourable friction surfaces, is no longer even a challenge for modern techniques, as already today in practice the merchandise is often shoved with the tips of the forks to its final place. On the other hand, the development of an automatic containerising device does pose a challenge. Its application is not limited to port operations, since it can also be used in manufacturing plants and intermediate storage, i.e., wherever the number of containerising operations is high.

8.3.3 Automatic Handling of Sawn Timber

Clearer shipping instructions and changes in the storage system would facilitate the development of automatic handling of sawn timber. Making the instructions clearer and "stowage-friendlier" would make it possible to lift several bundles at a time during the process of loading/discharging, as well as to determine the share of deck loads freely. This, in turn, would reduce the need for time-consuming arranging of the goods.

The storage system can be made to react immediately to the actual stowage operation by making certain changes in the system. Automated storage of sawn timber is particularly suitable at ports where sawn timber forms a considerable share of the total traffic of goods. A well-planned and well-organised automatic warehouse is completely independent of changes in shipping instructions. Each individual package of sawn timber can be found and fetched from the warehouse regardless of where the rest of the cargo for loading is located.

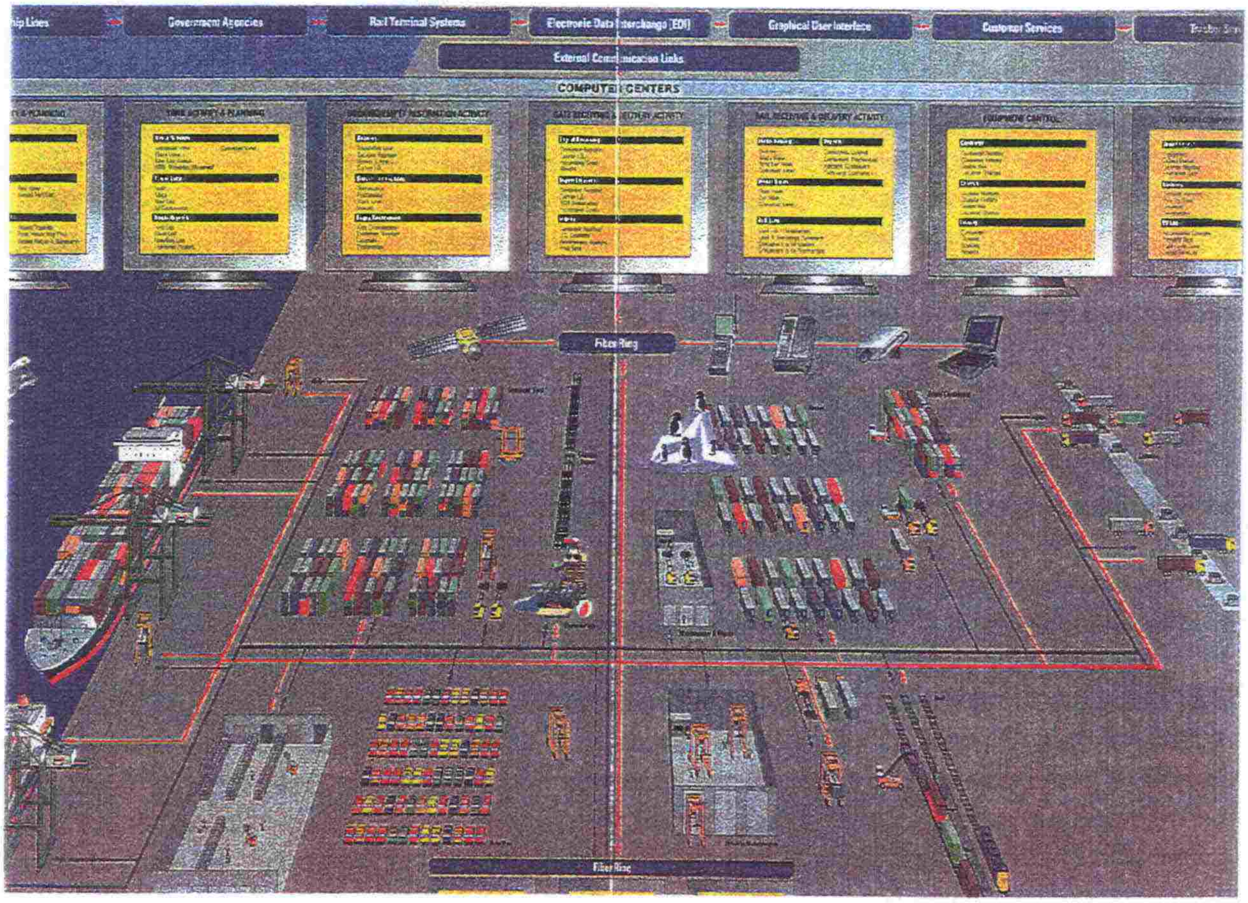
The shape and structure of a sawn timber package are suitable for automated handling without need for any special changes. The automated handling equipment itself can be a conventional, computer-guided high-bay store crane on rails. A system like this, in which wood is stored and fed out from the warehouse according to instructions given during the actual onboard loading operation, should minimise the bottlenecks. Automated cargo handling can, at its best, be almost unaffected by changes made to preliminary plans, which still are fairly common in practice.

8.3.4 Containers

For the time being, the container volumes at individual Finnish ports are small, and the operations of the container terminals are mostly based on the delivery of the unit directly to the consignee or consignee's representative. This may be the main reason why there has not been much interest in the development of automated terminal or handling operations.

The major reshipment hub ports (Europe, Far East), however, make use of highly advanced automation in container terminals, including control and management systems. Figure 34 shows an example of a container terminal in which the internal information flows are managed by means of a satellite connection with laptop computers, cellular phones, and camera surveillance.

Figure 34. Computer-controlled warehouse management is gaining ground in major overseas container terminals.



In container handling, the control system forms a part of the automation, and, e.g., the vehicle driver who receives his instructions from the automatic control system should also be seen as an element in the automation.

In Finland, the basic elements of container handling automation might include, e.g., an efficient information chain outside the port, connected to the handling systems controlling the operative functions and to the wide-gauged container crane/yard crane. The benefits of the wide-gauged container crane (see Figure 35) can best be seen in the fact that the ship's cargo can be both loaded and discharged utilising the container yard between the gauge as a buffer store.

Figure 35. Wide-gauged container crane

The wide-gauged crane renders itself to automation more easily than the conventional container crane. The control of operations is based on instructions displayed on the monitor screen, and the commands come from the outside. Nevertheless, the actual physical driving is still carried out by the crane driver.

The role of the port as a link in the transport chain has changed sharply during the past few years. The change process continues, and the development may alter the port's traditional role as a storage site to an efficient site for cargo transfers between different modes of transport. JOT/JIT deliveries would minimise the storage demands practically down to nil, resource planning would be made flexible by up-to-date control systems, and traffic would be a continuous, uninterrupted process. This would demand complete information flow between all parties involved, as well as 24-hour operation outside the port as well.

8.4 Economic Evaluation of the Alternatives

An analysis of the profitability of the operations of the transport chain may be approached in two ways: 1) as an integrated handling operation forming a part of the transport chain, or 2) as an independent operative function.

When assessing the profitability of a part of the transport chain, it is necessary to estimate the importance of each subsector for the integrated whole. In a competitive situation, it is occasionally necessary to compensate the costs of an unprofitable subsector by the profit from another. In the context of this study, terminal costs have first been examined as individual handling functions adding up to the normal terminal services: *containerising, unitising and storing* before loading and shipment.

8.4.1 Terminal for Chemical Wood Industry Products

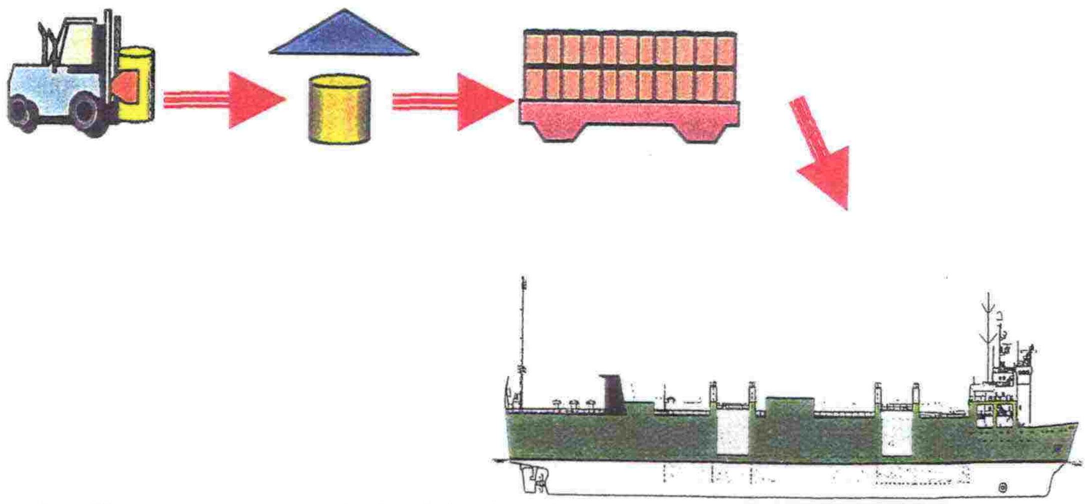
The vehicle and its driver form a close-knit unit, whose investment and operational costs make up the majority of the costs in the handling phase. The share of the driver is about 40% of the costs, while the machinery with its attachments account for the remainder. *Cargo registration, or "tallying", is a additional operation that is charged per ton or per unit.* In the example, identification (tallying) is assumed to be automated in both alternatives.

Apart from the driver and the truck, reel and pile clamps and grippers are needed in cargo handling. Their share of the total costs of the operational unit is a little less than 3.5%. Considerable savings can be achieved, if the cargo handling attachment can be installed to another, driverless cargo transfer unit.

Two examples of port terminals are used here to illustrate the cost comparison. Both ports are assumed to have an annual capacity of 270 000 tons of paper reels, with a storing period of 5 days. Of the total flow of merchandise, 35% is containerised, 45% unitised, and 20% loaded as StoRo cargo. Of the total merchandise to be containerised, 50% is stuffed directly from the land transport vehicle and the other half is circulated through the warehouse. 70% of the unitised cargo is loaded directly on flats, while the remaining 30% require storing.

Figure 36 illustrates the reception, storage, unitisation and loading of the goods.

Figure 36.



The necessary handling operations with the driver/truck/clamp system require 4.7 pcs of 3-ton units and 1.45 pcs of 12-ton units. In the automated alternative, the corresponding number of units needed is 4. The operations in the comparison are: reception, storage, unitising, and containerising. Table 3 below shows a comparison of the costs of an automatic system and a system using conventional, lift truck-handling methods.

Table 3

Annual capacity (tons)	**275,210**

Automation	
Annual capacity (tons)	**271,469**

Automated handling system					
Handling times	4	Price / Unit	Interest	Time in Use (a)	Annuity/ year
Automated handling	2,000,000 FIM	500,000 FIM	6.5%	12	245,136 FIM
Support rails	1,200,000 FIM	300,000 FIM	6.5%	12	147,082 FIM
Roller conveyor	400,000 FIM	400,000 FIM	6.5%	12	49,027 FIM
Control system	400,000 FIM	400,000 FIM	6.5%	5	96,254 FIM
Clamp	600,000 FIM	150,000 FIM	6.5%	12	73,541 FIM
Containerising automate	750,000 FIM	750,000 FIM	6.5%	12	91,926 FIM
Total	*4,600,000 FIM*				*702,966 FIM*
Maint. / spares / lubrication	% of capital				
And other costs / year	9.0%				414,000 FIM
Operator costs / year					188,916 FIM
Total costs / year					**1,305,882 FIM**
Tons / year / unit	**67,867**			**per tonne**	**4.81 FIM**

Conventional (transp./truck/clamp)	pcs	Price / Unit	Interest	Time in Use (a)	Annuity/ Year
3 ton truck	1,178,982	250,000	6.5%	6	218,504 FIM
Clamp	707,389	150,000	6.5%	12	86,703 FIM
12 ton truck	1,015,549	700,000	6.5%	7	167,293 FIM
Clamp	130,571	90,000	6.5%	12	16,004 FIM
Total	*3,032,490 FIM*				*488,504 FIM*
Operation costs	From capital				
(maint., spares, use)	16.5%				500,361
Oprators' salaries					1,251,138
Total costs / year					**2,240,003 FIM**
Tons /year /unit	**44,628**			**per tonne**	**8.14 FIM**

The above table gives a comparison of the equipment investments of two terminals with the same capacity, as well as the annual operating costs and their effect on the cost per ton. The table takes into consideration only those basic assumptions that can be regarded as directly comparable between the alternatives.

The salary costs of the lift truck drivers are based on the assumption of 1 driver per vehicle per year. In practice, two-shift work requires the work input of more than 2 drivers per vehicle, taking holidays and other similar factors into account.

8.4.2 Required Equipment Investments

The equipment investments of the automatic system are estimated at about FIM 4.6 million, and the annual operating costs, including the supervisor, at FIM 1.3 million. The cost per ton is approximately FIM 4.80.

The initial costs of the driver/truck/attachment alternative are lower, around FIM 3 million. The annual operation costs, on the other hand, are considerably higher, amounting to FIM 2.2 million.

The handling costs per ton are thus FIM 8.14. In this example, both handling systems are assumed to function without additional transfer costs.

The development of automatic loading/unloading equipment and storing systems aims not only at expedited cargo handling but also at a reduction in operating costs. The most simple alternatives have often proved to be the most reliable in operation, and consequently, the maintenance and repair costs are lower.

The effective life span of the automatic equipment is calculated at 12 years. The life span of a lift truck is 6-7 years and its salvage value around 10-15% of the procurement cost.

9. RESULTS, SUMMARY AND DEVELOPMENT OF SUBSECTORS

9.1 General

Even though separate, individual technical development models are being developed and created continuously, the integrated development of the different links of the transport chain has proved more difficult. The large-scale suppliers of paper and sawn timber, e.g., have usually embarked on development cooperation only in cases where the coordination or financing of the project has come from an exterior source.

The automation and mechanisation trends in Finnish ports and vessels has been examined in this study taking into account the entire transport chain. The purpose has been to identify those parties outside the actual ports, that have significant influence on duration of flow-through in the port and the whole delivery chain. In addition to increasing the efficiency of port operations, it is also important to consider the interests and requirements of the basic industries of Finland. In other words, the primary goal in the development of the manufacturing plant, port operator and shipping agencies should be to study and adopt economical transport units and systems with optimal space-use, covering the entire transport chain.

The different parties within the Finnish transport chain have succeeded in developing various devices and sub-systems which enhance the quality and speed of cargo handling. Some of these innovations are simple mechanical devices, whereas others apply sophisticated mechatronic technology. Until now, less attention has been given to control systems and the transport chain as a whole. In order to proceed with the automation efforts, it is necessary to determine the needs as well as the goals. This might involve a more detailed description of the roles of the parties, and their specialisation in handling fewer categories of port-specific merchandise than today. Some of the Finnish ports could, therefore, become more distinctly specialised, and at the same time, seek to identify new cooperation partners for the development of port operations.

The state authorities have initiated several studies and measures aimed at developing the transport operations, channelling the practical implementation through the Ministry of Traffic and Communication and the Technology Development Centre TEKES.

The project "Development Programme on the Operation and Technology of the Transport Chain (KETJU)", initiated in 1998, forms an important part of the development efforts in the field of transportation. The time appears to be right for the implementation of the visions of various studies and concepts into operational systems and equipment.

9.2 Cargo Handling and Its Development in Finnish Ports

A trend common to all Finnish public ports in the 1990s is a notable increase in the volume of unitised cargoes in overseas traffic. This is a universal trend. However, depending on the size and the resources of the port, the adaptation to handling of ISO containers has varied: in fact, there are several very different kind of handling systems currently in use for intermodal units.

Another feature common to Finnish ports is their versatility and a certain lack of specialisation. Due to their general character, nearly all the ports in Finland are able to serve all ship types carrying breakbulk cargoes. This enables a wide clientele, but on the other hand, the increase in volumes and efficiency and the cost savings resulting from specialisation remain out of reach. Cargo handling in the ports, its various phases and development trends is summarised following sections.

9.2.1 LoLo Systems

The method is used in the cargo operations of both conventional and modern cellular carriers. In this context, conventional carriers refer to ship holds that are very varied and where loading and discharging require a considerable amount of manual work. The LoLo system is also applied in cargo handling on the weather deck of RoRo carriers.

The cranes used in Finnish ports are mainly level luffing and gantry cranes. The operating speed of the level luffing cranes, e.g., in handling intermodal units is considerably lower than of gantry cranes. A new type of versatile, mobile crane with rubber tyres is becoming increasingly common. In Finland, the turnaround time of LoLo carriers is usually longer than that of RoRo vessels, because it is very seldom possible to handle the ship's cargo with more than one crane at a time.

9.2.2 RoRo Applications

There are several concepts of this type in use at present. Their main characteristic is that the cargo is moved on board/off board on wheels. After the transfer onboard the ship, the load may be left on its flat or moved to its final position with a lift truck (StoRo). The carriers can be equipped with stern, side or aft doors. One of the strengths of this application is its versatility, as the carriers can transport breakbulk cargo as well as intermodal units. However, this type of vessel sets special demands on the berth structures.

The utilisation rate of the RoRo carrier holds is often lower than of LoLo vessels, as the cassettes and terminal trailers take up space and reduce the utility load. In the StoRo systems the holds are utilised better, but the loading/discharging is slower and the positioning and securing of the load is more complicated. Therefore, to save time, the security regulations concerning the fastening of cargo are not always followed. RoRo carriers are quite common in Finnish seafaring: e.g., some 50 RoRo carriers pass through Helsinki port weekly, while the corresponding number of container carriers is only 20.

9.2.3 Terminal Operations

This section deals with the systems related to cargo handling at port, which make the port area operational and support the loading and discharging of the vessels, as well as land transports. These subsectors are very important for the general performance of the port.

9.2.3.1 Internal Transfers

An efficient internal transfer system is necessary to maintain the desired level of flow-through at the terminal and to meet the requirements of the shipowners and customers. In Finnish ports these internal transfers are carried out using a wide variety of techniques.

The increase in unitised cargoes has enabled some ports to make substantial investments, e.g., into the development of container handling. In spite of this, the variety of the equipment and its application for the same purposes has an adverse effect on the general efficiency of the port. If the operations of a container terminal are based on the use of straddle carriers, for instance, there should be no other, slower machines in the operation area or activities not related to container transfers.

It would be advisable to identify the type of concept best suited for each transport need, and then standardise the practices correspondingly. The desired result cannot be achieved merely by investing into efficient machinery and equipment, unless the new system is designed to form an integral part of the whole.

The development of unit handling techniques is considerably more simple as compared to handling of breakbulk traffic. Nevertheless, breakbulk cargoes will always occupy a position in Finnish foreign trade. It would, in fact, be worthwhile to study the most suitable techniques for serving this form of cargo traffic.

9.2.3.2 Port Gate Functions

The functions at the port gate and entrance monitoring are taken care of manually in Finnish ports. At the port of Helsinki, e.g., more than 1000 trucks deliver or pick up merchandise every day. Management of such an amount of information with the conventional system requires a great deal of resources and is difficult. The automation of entrance monitoring and the resulting benefits are closely associated with the computerised information system controlling the physical cargo handling at port. The importance of this subsector and the interest in its development has risen considerably during the past few years. Some projects related to this issue are currently being initiated. The objective is automatic identification of all the units and vehicles entering and exiting the area. The achieved benefits would be a reduction in the time lag in information transfer and a decrease in the manual workload. The automation of the gate functions would also improve the service level and smooth implementation of land transports as far as port area operations are concerned.

9.2.3.3 Storage and Other Services

The port storage facilities offered to exporters are mainly used by forestry companies, whereas the number of users of these services in the import sector is much higher. A common feature in port warehousing is that there is a lot of room for improvement in the operating practices. Certain special solutions are in use, however, e.g. the modern reel clamps and the automatic loading and unloading systems for paper reels. Nevertheless, in several cases it is only a question of an individual application, without linkage to the port's warehousing or cargo handling as a whole. The company using the services has externalised a part of its business activities and the port operator has developed its operations for the purpose, but the development of automation of the port warehouses at a general level has been given less attention.

One of the most important advantages of the use of intermodal units is the considerably reduced number of cargo handlings in the course of the transport chain and elimination of the need for covered storage areas. A majority of cargo unitising related to the Finnish forest industry and other basic industries is still carried out at port. This means that the cargoes may have been handled three or more times before it is taken onboard in intermodal units.

9.2.4 Development Targets

There are several different systems for the mechanisation and automation of cargo handling. Therefore, it is really a question of combining the different techniques and adapting them for new applications. One approach to the development of cargo operations is partial automation, This would appear to be the best solution in view of the size of Finnish merchandise flows, since reaching for completely automated port operations is very expensive and the achieved benefits do not correspond to the investments. It would be important to identify those sub-functions whose automation would result in added value to the whole transport chain at a justifiable cost.

9.2.4.1 Cargo Handling Onboard the Vessels

The innovations for the vessels at berth aim at shortening the lay times and boosting the handling of cargoes. In general, this means improving the interface between the port and the ship in order to speed up the loading and discharging functions. With reference to onshore operations, development is focused on enabling simultaneous operation with two or more cranes or ramps to expedite cargo handling. Improvements in vessel design aim at simplifying the hold space, which works towards the same goal. The semi- and full-automatic cargo lashing systems, which are in use or being developed applying current technologies, require the use of uniform intermodal units.

9.2.4.2 Port Operations

One of the possibilities for boosting operations and increasing the profitability of ports is through specialisation and development of new operational concepts. This means that the port can continue to provide services to different types of ships, but that it should have a clear line of specialisation, as well as specific areas of operation for the various transport modes.

The increasing popularity of intermodal units in overseas transport provides a sustainable basis for specialised ports to build on and develop their operations. Raising the automation level of internal transfers, e.g., is much easier in specialised ports than in ports handling conventional breakbulk cargoes.

There are certain factors related to the intermodal concept, whose importance for the port will keep growing in the future. Ports will need to develop their stuffing and stripping operations, e.g., by procuring systems for automatic stripping into the warehouse and corresponding stuffing into containers from the warehouse. Land transport sets its own demands, not only on cargo handling at port, but also on the information system controlling the operations. The less time it takes to identify a unit arriving in the area, the sooner the handling instructions for the unit will be received. This will also improve the planning and anticipation of operations.

9.3 Development Prospects

A basic prerequisite for the development of new and improvement of existing transport chain systems is to agree on the adoption of a compatible control and management system by all parties, with an easy-to-use identification system as its key function.

The joint development measures of the near future will be influenced by the international mergers of paper manufacturers. Their impact on the development of the transport chains will only become evident after a number of years.
The objective in developing the transport chain is to create a general system which would meet the requirements of the Finnish forest-based and other industries. One of the questions deserving serious consideration in this context is whether it would be possible to achieve more functional alternatives by focusing on the automation and mechanisation of smaller-scale, uniform subsectors with clearly defined merchandise flows, instead of larger entities.

The transport chain within the export industry requires information exchange at the national level between consignor, provider of land transport, shipping agent, operator, and shipower. This link does exist and it is working, but it still is not sufficiently reliable for monitoring the merchandise in the transport chain and the related information. A speedy joint data exchange system is essential for the development of automation. Finland has advanced know-how on data transmission technology and its practical applications. Finnish experts are also involved in the development of world-wide logistic tools, such as TEDIM (Telematics in Foreign Trade Logistics and Delivery Management) and Tradex (Traffic Data Exchange).

9.3.1 Development Prospects in Container Handling

The goal in port operations, as elsewhere today, is to obtain the highest possible rate of profitability. The complexity of studying this issue can best be seen in container transport and especially in their storing. The developments in land prices make it necessary to pile containers into higher and higher stacks. Due to the longer container handling times, this may decrease the total profitability of the transport chain. The positioning and removal of the containers from the stacks set higher demands on the storing and monitoring systems, as well as to technical solutions regarding container handling equipment.

Given the current traffic flows in Finland, it is not economically feasible to implement an integrated, automated container handling system in the individual terminals. Since improved control systems for container handling are inevitable, it would instead be worth studying to what extent the various components of the system could be profitably automated. At the same time, the possibility to utilise these automated services outside working hours should also be examined.

The findings of the study "Merchandise Flows, Operation Capacity and Development Needs in Ports 28/98", assigned by the Ministry of Transport and Communications, show that working time arrangements and service factors are important targets for development. An automated unloading/loading system, activated by the truck driver, enables night-time unloading or loading of a truck without other personnel, or even without entering the port area itself, which is an advantage considering security aspects. However, this means that customs clearance and other formalities have to be carried out in advance during normal working hours.

Together with the development of the automated container handling, it is necessary to study the development of control systems for empty containers. The nation-wide system should also serve the customers whose volumes of exports/imports are relatively small. As an indication of what can be achieved by practical development measures, the following charts describe the improvement of the efficiency of a port operator as a result of higher specialisation and partial automation. The impact of various development measures on the number of lifts is shown in Figure 37, and on the increase in the operator's turnover per employee in Figure 38.

Figure 37. Development in number of lifts at port operator's container terminal, average lifts per crane-hour per year

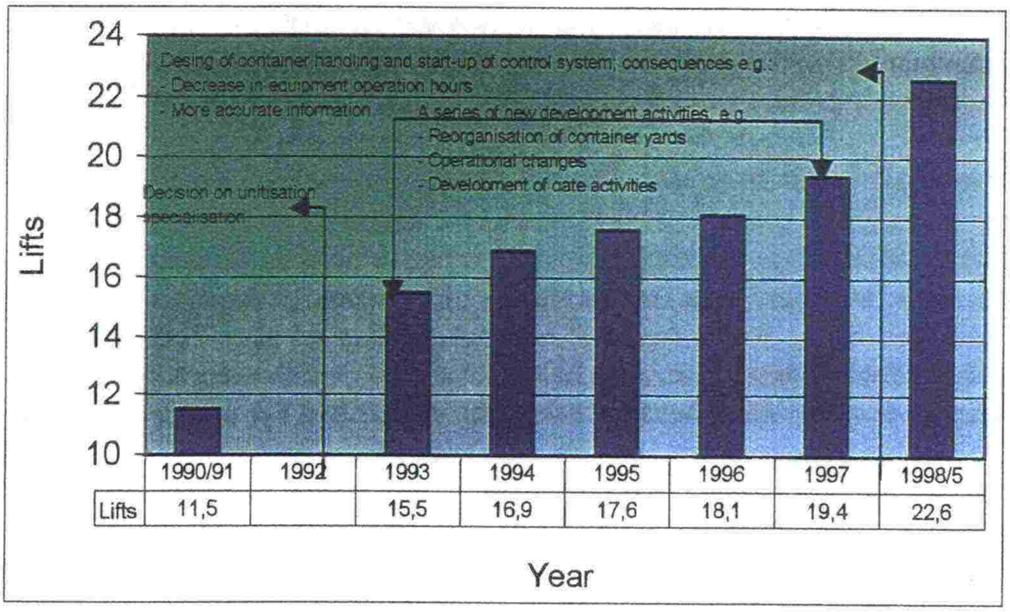
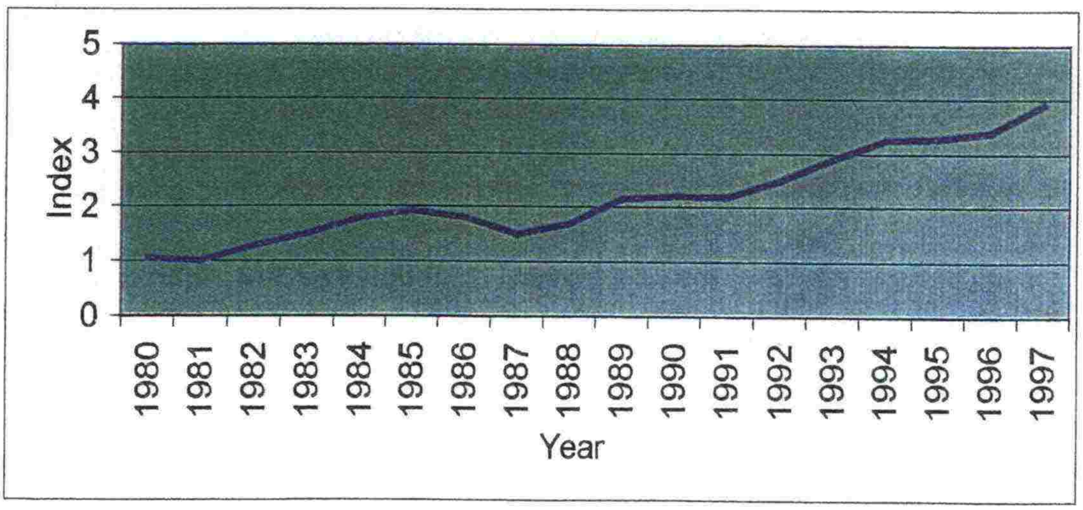


Figure 37 presents the impact of development activity on the amount of hoists. The operations are given as texts in the figure. Figure 38 presents the impact of the development activities in increasing the operator's turnover per worker.

Figure 38. The increase in the operator's turnover per operative.



9.3.2 Development Prospects in the Chemical Wood Industry

The cost comparison in Table 4 shows that the handling costs of chemical wood industry products are lower when automatic handling systems are applied (see details in Section 8.4.1). The investment in equipment and the annual operating costs have been converted into their current value. The calculation demonstrates that the cost saving achieved with an automatic system is approximately FIM 6 million.

Table 4.

Current value (FIM)		
	Lift truck -based handling system	Automatic handling system
Operating costs, FIM/year	2 240 003	1 305 882
Operating costs, current value (12 years, interest rate 6.5%)	18 275 572	10 654 334
Investment in handling equipment	3 032 490	4 600 000
Total investment (current value)	21 308 062	15 254 334
Investment cost savings (FIM) (current value)		6 053 728

Both the technical implementation and the economic benefit of the concept have been studied. The findings support the view that the concept can be implemented in practice to form a functional product, an automatic handling system.

Apart from the above benefits, other aspects worth noting include factors which improve occupational safety (i.e., related to noise, vibration, unergonomic driving position, etc.), as well as those which reduce environmental damage (i.e., related to exhaust gases, tyre-wear, lubricant leakage, etc.).

The structural change in the Finnish forest industry continues, and operations are concentrated to ever fewer and larger companies. In the first phase, the change is effected in the form of mergers between companies. As a result, there are now three large forest industry groups in Finland: UPM-Kymmene, Stora-Enso and Mesä-Serla.

The next phase is focusing on the intensive development of logistic systems. One example of this is the long-term transport contract signed by UPM-Kymmene with the shipowner company Splithof for transatlantic traffic to America. The Stora Group had already initiated the improvement of its operative logistics before the merger with Enso. The Stora system, dealt with in more detail in Section 7.4.2, is considerably more sophisticated than that of UPM-Kymmene.

The forest industry is becoming more and more universal, as companies expand their operations from the traditional market areas to new continents. The concentration of activities sets new challenges for automated cargo handling, but at the same time it also offers opportunities for the development of new systems.

As the operations of the forest industries become more market-driven, the role of information systems also changes. Uniform and reliable information and data management systems are essential for all parties involved. This is connected to the goal of these companies to improve the efficiency of their logistics chain, especially as regards the reliability and quality of their deliveries.

The growing environmental awareness of the customers influences the development of the industry. The forest industries are increasingly adopting a uniform operating model which covers all parties in the transport chain and supports global operation. The decisions made within the industry today are becoming more customer- and demand-oriented.

9.3.3 Development Prospects in Sawnwood Products

Automatic high-bay stacking might provide a solution for storing sawn timber, which takes up a great deal of space. Collaboration between port operators and wood suppliers can produce new innovations based on current know-how and techniques.

Sawn timber will, nevertheless, most probably continue to be stored at port. The fluctuations in demand due to raw-wood market prices can only be buffered at ports in practice, due to the limited storage possibilities and long haulage distances of the sawmills. Product quality demands and customer preferences are the main reasons why JOT/JIT deliveries are not easy to accomplish in sawn timber transport.

The increasing unitising of sawn timber improves the anticipation of shipments. The future trend is towards containerising of sawn timber, which will enable transport by regular line traffic. This will enable deck loading more frequently than today, and the quality of transport chain will improve.

Automatic identification of sawn timber products needs to be developed in order to enhance the possibilities for accurate and up-dated information, e.g., on the situation in the warehouse and loading operations. Advanced merchandise identification systems may also expedite the preparation of stowage plans and shipping documents.

9.4 Conclusions

9.4.1 Basic Requirements for Automation

Ports will have to face many new challenges in the future. The most important of these demands include:

1. "Correct location" of the port with regard to distribution of merchandise. Being efficient is no longer the only significant factor. This applies especially to goods that are containerised.

2. Fast cargo handling, which can only be achieved by:
   - developing and modifying the present working hours, and
   - increasing automation and mechanisation.

The delivery times from plant to customer have become clearly shorter. Requirements for speed and quality in the transport chain will keep on growing, setting new demands on the management of the chain as well as on its individual components.

3. Adoption of scheduled timetables in sea traffic, with an accuracy in the range of one hour.

4. Development of data transmission and general control systems.

   The key to efficient operations at port and its terminals is timely data reception and processing. The more advanced the cargo handling system is, the more sophisticated the control system should be.

9.4.2 Present Status in Use of Automation

Ports will not be able to deal with the challenges of the future without adopting automated cargo handling and new concepts. The development and automation of port operations is, in fact, under way in many of the world's major hub ports.

At the ECT container terminal in Rotterdam, automation has been in use already for a number of years in container transfer to the container terminals, stacking in the warehouse area, and loading of the transport vehicle fetching the cargo.

In Singapore, the automation of Ship-to-Shore cranes is an ongoing development target, and meanwhile, Noell is developing an automatic straddle carrier at another port. Taking these "links" into use will create an automated container handling chain within the port area from the ship to the port gate.

Moreover, the possibilities for automated land transport are being investigated in Holland within the framework of the RoadRail project. In the most sophisticated form of this system, the vehicles would drive among the rest of the highway traffic, fully dependent on automation.

The situation is being carefully monitored in Finland. The basic requirements for partial automation of cargo handling are already there. The design and adoption of new systems may be expedited by the 3-year KETJU development project for intermodal transportation, implemented by the MTC and TEKES.

9.4.3 Automation Onboard Ships

Onboard automation has been applied for quite some time in the use and control of devices. The relatively low level of shipbuilding costs in the long term has led to ever larger vessels. Container carriers of 6000 t.e.u. are being constructed today, and vessels of 7000-8000 t.e.u. are being designed. Such voluminous ships set completely new demands, e.g., on handling systems and port structures.

Even though the huge container carriers in intercontinental traffic do not enter Finnish ports, the target of increased efficiency also compels Finland to consider the demands of automation on the integrated transport chain and to apply automation where appropriate.

The majority of Finnish seatraffic is shortsea shipping, but the developments in deepsea traffic are directly reflected on it. In recent years, the size of the vessels has grown also in shortsea traffic along with increased velocity. Despite the larger volumes of breakbulk cargo, the port operators must get the vessels out of port within the same time as before. This applies particularly to container feeders and RoRo vessels. Automation is, in fact, being currently introduced into the RoRo system. The recently published "Stora concept" enables the automatic drive-in of haul wagons onboard and partly automated lashing.

Although the size of the vessels has increased, the turnaround times have either shortened or remained the same. However, the cargoes to be shipped enter the port area later, i.e., closer to the onboard loading time. This emphasises the need for fast identification of the goods and easy warehouse management in the future.

In Finland, the automation of onboard cargo handling has been studied innovatively from many perspectives, e.g., at the Masa-Yards department of technology. Automated cargo handling equipment can thus be installed on the ships whenever considered necessary.

9.4.4 Need and Possibilities for the Adoption of Automation

The more frequent use of containers, growing cost awareness, problems related to labour, and changes in ship types are increasing the pressures to develop terminal activities by means of automation.

It is quite possible that this will lead to a point where the conventional operation concept of terminals will no longer be applicable, e.g., with intermodal transports. Continuing the operations with the present concept will keep raising the space requirements at the ports. In order to curb this growth, machinery should be developed capable of stacking ever higher piles, operations made more flexible, or storage times shortened and other handling of goods at port reduced. The automation of operations is one answer to the problem.

It is technically possible to construct equipment that is larger and more efficient than today. However, the practical implementation of such equipment is questionable, due to high investment costs and certain operational factors. The main attention in developing the transport chain should, in fact, be focused on rearrangement of the chain links and modes of operation, e.g., through the following measures:

- Intermodal units will be stuffed already at the manufacturing plant instead of at port; and/or:

- Wherever formation of units at the plant is not feasible due to lack of space or working hour arrangements, inland terminals will be constructed to perform unit handling, transfer and control.

- Ports will apply as much automation in handling operations as possible.

Solutions to the problems can be sought by the terminal operator in collaboration with the consignors and transporters. If one party alone is involved in the development efforts, some of the links will be improved, but not the system as a whole. Moreover, even though development work is focused on only parts of the system, all of the parties to the transport chain should participate in order to ensure that the connection points to the developed link are functional.

The simultaneous automation of the whole transport chain, or changing the activities from manual to automated all at once, is unlikely and difficult to control. It might be advisable to continue along the chosen path, i.e., by automating those links that have major influence on the entire chain and its operation as a whole. Such activities might include unloading and loading of land transport vehicles, lashing of RoRo flats, and stuffing of containers. The automation of these links would improve the utilisation of the night shifts at ports. Automation would, for its part, also relieve the manpower shortage, as the night shifts would require less personnel than today. Personnel needed to monitor the operations would be sufficient for maintaining the automatic procedures.

The adoption of automation at ports causes several changes in operations. It affects the layout and size of port warehouses. The length/width ratio will change, the size will grow smaller, and internal traffic in the stores will be reduced. The change also improves, e.g., occupational safety. The smaller size of the warehouse makes it possible to limit the growth of the port area and achieve a more efficient layout.

According to several forecasts, European highways will become even more congested in the near future. The EU Commission has therefore recommended certain measures by which merchandise flows could be transferred to a larger extent from the highways to the waterways and railways. In order to attract consignors away from road transports, for instance to combined transportation, the future intermodal terminals should be as small as possible and as cost effective as the other available alternatives, i.e., road transport terminals and central warehouses. The port terminals should also be designed so as to avoid intermediate handlings and transfers within the area.

Specialisation of terminals and ports is needed to meet all the requirements of shipowners and other port customers. The adoption of automation can be seen as one solution to the increasing demands, as it improves the efficiency of cargo handling and enables a relatively larger flow-through of goods in the present port areas. Economic considerations dictate that the merchandise flows in the automated or semiautomated ports must be increased.

The automation of cargo handling in Finnish ports and vessels is only taking its first steps, as shown in this study. This can partly be explained by the small flows of goods. There is no fully automated, integrated system in use, but some individual pilot equipment is being tested at some ports. Functions related to the handling of containers and other unit cargoes are a potential target for automation development in the future. Even today there are various machines, devices and techniques as well as systems available, which could as such be taken into use at ports and port warehouses. Part of them can also be applied in other links of the transport chain.

APPENDIX:

CARGO HANDLING AUTOMATION ON FINNISH VESSELS

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LIST OF FIGURES

1. INTRODUCTION

1.1 Foreword

From the shipowners' point of view the vessel represents an asset, and it is therefore essential to maximise the volume of transported cargo per time unit to ensure efficient use of the capital invested. Shipowners have tried to increase their cargo income and improve profitability by investing in bigger vessels, but as the ship size increases, the turnaround time at port must be shortened to achieve this goal. Different studies have shown that, apart from increasing the velocity of the ships, investments into cargo handling to shorten the turnaround time have great potential for improving the performance of shipowners.

The ship represents one link in the transport chain. How do the other links in the chain, the transported cargoes and the changes in the customer needs, affect the vessel? How will the ship develop and change as one of the links in the chain? The mechanisation of cargo handling, e.g. unitising, has already considerably changed and boosted cargo handling. One central question in this context is: will mechanisation and automation of cargo handling be implemented on the shore, on the ship, or both?

The objective of this study is to provide information on the level of mechanisation and automation of cargo handling in Finland, and the innovations applied to reach that level.

1.2 Implementation of the Study and Data Collection

Several telephone conversations and interviews on mechanisation and automation issues were held with Finnish shipowners, docks, consultants and manufacturers of cargo handling equipment. A significant part of the study is based on material from these sources. Bibliography on the subject and relevant patents were also reviewed.

According to the scope of work, the study concentrates on innovations designed or utilised by Finnish or partly Finnish parties. Some foreign innovations are presented when they are connected with the Finnish solutions in some way.

There are some ongoing Finnish or bilateral projects on cargo handling, on which there is no information available due to their confidentiality.

2. Development of Automation in Onboard Cargo Handling

2.1 Mechanisation and Automation of Work

Three different types of elements can be observed in dock work: manual work, mechanised work and work which is information-intensive and involves automatic data processing. These different types of activities are carried out parallelly. At the moment several basically simple and often repeated tasks are only partly mechanised, and involve a lot of manual work. A good example is the identification of the cargo units, where the human eye and manual feeding into the system are still needed. In the industrialised countries, labour costs often play an important role, and the trend is to decrease the share of the mechanical and monotonous activities carried out by the workers.

The progress of integrated operations and individual work phases to the next element is defined, besides by technological developments, also by the economic and political possibilities to implement the change.

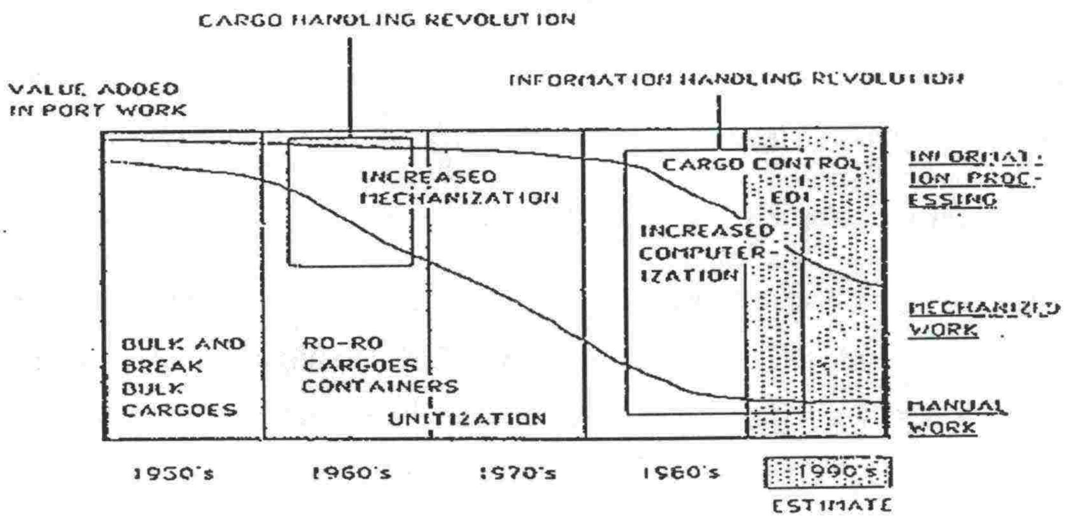


Figure 1 **Change in port operations since the 1950s (Source: Ojala, 1991)**

The change that has occurred in port operations is naturally easy to see in the development of cargo handling, and the same overall pattern can be observed in society, where the mechanisation and automation of production activities is a general trend in industry and trade as well as in the service sector. The development of intermodal philosophy within the transport sector is a part of this development towards industrialisation of operations and shift towards mass production. In practice this means that cargo handling is also moving from a labour-intensive to a capital- and know-how -intensive direction.

The same general principles apply to mechanisation and automation onboard the ship as at ports and terminals. Still, some additional motives and limitations are involved on the ship.

Below is a list of some reasons for the automation of onboard cargo handling:

- Reduces or eliminates the dependence on the labour force at port (e.g., role of strikes);
- Decreases the peaks in labour force and equipment requirements during the turnaround time of the vessel at port, and enables work in three shifts at the terminal;
- Expedites cargo handling
- Increases productivity (eliminates inefficient work phases through mechanisation and unitising);
- Eliminates human labour from hazardous work phases or locations, e.g., ship holds.

Mechanisation, and automation, when feasible, is focused on repeated, similar work phases. Depending on the ship's cargo handling system, there are relatively few such work phases. Before being able to proceed with automation, the cargo handling processes have to be standardised. Along with development, the share of manpower in cargo handling will decrease as a whole, but, along with mechanisation, the human contribution is shifted to some extent from machine operation to maintenance and repairs.

2.2 Important Design Factors

The following technical factors have to be taken into account in ship design and engineering:

- Effect of the technical alternative on the ship's weight
- Adequacy of technical know-how
- Product technology
  - Construction facilities
  - Price
  - Implementation schedule
- Complexity of the technical solution
  - Need for maintenance and repair
  - Reliability
- Principal dimensions and form of the holds
  - Seaworthiness
  - Safety (e.g., risks in RoRo holds)
- Holds
  - Utilisation rate
  - Ease of cargo fastening
  - Weather and sea rolling limitations, heelings with regard to cargo handling
- Possible technical risks in new techniques.

Economic and political issues:

- Price
- Operating costs
- Labour costs vs. investment and operating costs
- Existing physical structures - availability or lack of port machinery and equipment
- Suitability for target traffic - port size, capacity balance
- Operational risks not taken into consideration in the new design
- Existing organisational and political structures or lack of them
- Attitude of trade unions

- Insufficient competition for various reasons
- Psychological effects of recent recession.

2.3 Importance of the Characteristics of the Handled Cargo

The characteristics of the cargo are very important in the mechanisation of cargo handling on the ship as well as at the terminal. The issue is examined below from the perspective of onboard cargo handling.

The physical dimensions, weight and compactness of the cargo determine the demand for hold space and shape and utilisation rate of the holds, as well as the weight sensitivity of the vessel, and the need for ballast systems. The sensitivity of the cargo to damage determines what methods to use in gripping the load, possible need for weather protection during handling, and the means of fastening the cargoes. The features of the cargo also determine the solution to a fundamental problem: how to identify the cargo units automatically during handling. The uniformness or diversity of the cargo is very significant for its identification and automation. Therefore, it should be unitised and standardised.

2.3.1 Unit Cargoes

Units offer a better possibility to mechanise and automate cargo handling than breakbulk. The trend is towards cargo unitising, because the number of cargo handlings can then be reduced and the damage of risk decreased. The minimum unit size should be, e.g., 10 tons. The cargo should preferably be unitised before entering the port.

One of the most important innovations pertaining to bulk and breakbulk cargoes is the development of the standard container, in which the lifting points, e.g., are standardised. The containers are stackable, and consequently space utilisation is efficient. Cargo handling has been simplified and expedited, and is less labour-intensive. This invention has enabled cost efficiency and increased the productivity of labour and capital. Unitising makes full use of machinery, but, on the other hand, makes it necessary to use a wider range of equipment. Unfortunately all merchandise is not suitable for containerising.

The RoRo handling of units on trailers, terminal trailers and other towable units results in a high cargo handling speed, but in an inefficient use of surface area onboard, as the units are not stackable. Their automated handling is also more complicated than that of containers. The characteristics of cassettes will be presented in more detail later.

Standard units are not suitable for all cargoes, either due to physical or volume limitations, such as small size of consignments. This is the case in containerising of small consignments, e.g., as it causes a low stuffing rate. Additionally, the standard units are not necessarily suited to all vehicles. Therefore, there is a call for new units that are more suitable for intermodal transportation and different cargo types.

2.3.2 Paper Rolls

Automatic gripping devices are applicable only with a narrow sector of paper rolls, and therefore it is necessary to set weight and diameter limitations for rolls.

An opposite trend to automation is the reduction of consignment sizes in the paper industry. This reduces the possibilities of unitising. Also, the diverse cargoes demand different machinery and equipment (clamps, etc.) for their handling.

The rolls are sensitive to mechanical and weather damages. The hydraulic head clamp mainly grips the head of the roll, and if the grip is too strong, the roll is damaged. Still, clamps of this type are gaining popularity, since they do not set large demands on packing materials. The use of devices based on vacuum suction is decreasing. Head grippers can be used, but they set special demands on packing materials and reels. Side grippers tend to damage the shape of the roll, and are therefore almost extinct. For these reasons, paper rolls are normally unitised in ship handling, and handled, e.g., on terminal tractors with the RoRo system or on pallets with the LoLo system.

Another problem is the diversity of the mix of the transported goods. This is mainly due to two factors: the product assortment is very varied in the Finnish paper industry compared to, e.g., Sweden, and the transport alternatives are not company-bound as in Sweden. In addition to the fact that the volumes handled at the terminal can be large, the variety of the necessary handling machinery and equipment is quite wide as well.

A major problem is the identification of the roll. Bar codes are being utilised for identification, but the bars cannot be easily distinguishable against the brown packing paper.

Therefore, the operation requires sufficient lighting. Another problem is in identifying several rolls simultaneously, e.g., from a unit. In machine vision identification, the difficulties are partly the same, only that identification is based on the roll ID-numbers. The problem of identification based on radio technology and magnetic tape is the cost, but, on the other hand, it does enable the identification of several rolls simultaneously and is not affected by lighting conditions.

2.3.3 Forest Products and Pulp

Generally there is no specific lifting or transfer gear for forest products and pulp carriers, only holds with a straight wall or walls. These cargoes are not sensitive to damage. Normally they are handled in bundles or as pallets (pulp), and lifted in LoLo handling with slings attached to the loading device. The automation of their handling operations is not particularly easy. Pulp might also be suitable for containerising.

3. ONBOARD INNOVATIONS

3.1 LoLo Handling

In LoLo cargo handling, the load is lifted with conventional cranes, either with deck cranes or onshore or mobile cranes, vertically on and off the ship. The crane can be equipped with different types of grippers for different types of cargo. Traditionally, the cargo space on the ships consists of one or more covered holds. (von Bagh, 1988)

The mechanisation of cargo handling on conventional vessels is normally carried out by cranes mounted on the ship. Formerly, they were usually boom-type, manned cranes positioned on the deck. The load lifted with this crane type tended to spin around, but the crane does allow a higher deck load. The advantage is good control of the load. For the time being, the bridge-type cranes used in automatic warehouses (overhead travelling cranes) are not much utilised, and only in foreign applications.

The most important development step in LoLo handling so far was taken at the end of the 1960s, as the unitising of cargoes was developing. Cargo handling in container carriers is carried out in principle in the same way as in traditional breakbulk carriers, with the exception that the unitised cargo is fastened to the hold and to other units with container twistlocks and, when necessary, with special lashes, but still manually. The cargo holds on bulk and breakbulk carriers normally consist of one or more straight-walled holds, where the cargo is lowered, stacked and fastened into place manually. The cellular structure of the holds in many container carriers facilitates cargo handling and fastening. In these cases, the container runs along rails to the correct position and also secures itself into place for transport without manual fastening. In view of the automation of cargo handling, this ship structure has many advantages.

Some of the technical solutions and concepts developed for the mechanisation and automation of LoLo handling are dealt with in the following.

Loading rig construction on ships

The patent (42280) for this innovation was granted to Valmet Oy, Finland, in 1972. It involves a loading rig structure used on ships, which functions as a mechanism to stop the load from spinning around its vertical axle during lifting, and maintain a standard angle with the keel line of the vessel. There is no information available on whether this loading rig has been constructed or not.

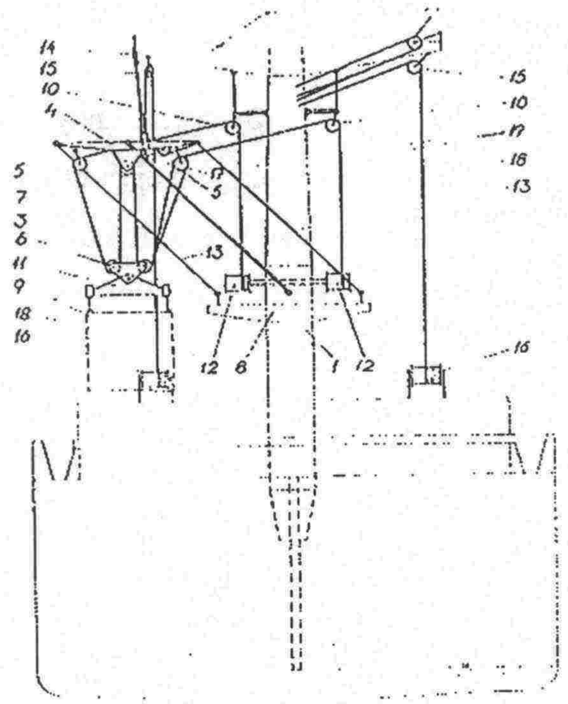


Figure 2 Loading rig construction onboard ships

Dock Express

Finnish Kone Oy has delivered gantry-type cranes for a semi-emerged Dutch dockyard-type vessel. This ship type has two cranes moving longitudinally on rails installed on the sides of the ship above the uniform hold compartment. At the aft of the ship there is a extension with rails reaching the berth. The cranes driven to the end of the rails carry out the vessel's cargo handling from this extension. These carriers are designed primarily for special project transports of large-sized cargo. Automation of this type of cargo handling is hardly rational. (Wijnolst et al., 1993)

A similar type of principle is utilised, e.g, in the Finnish Twinstar container carrier concept, to be dealt with later on, and in the CASH carrier (Ahlmark, Sweden) for the handling of cassettes, in which the cranes are mounted below the deck.

The experiences with Dock Express -type vessels have, in turn, also led to the emergence of open, unhatched container carriers.

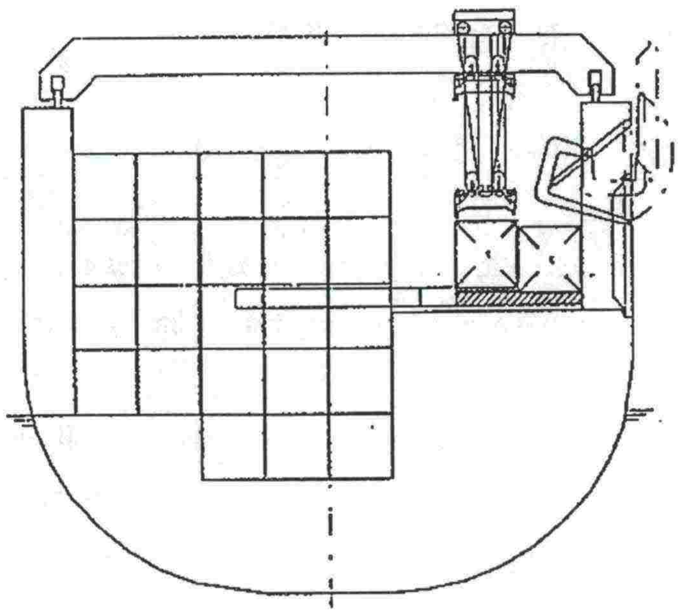
Gantry crane application on ships (concept)

The affiliated company KCE Konecranes of Kone Oy is presently participating in the development of a gantry crane application in a vessel design project of Kvarner Masa-Yards. This crane solution appears to be based on a standard product and includes an automatic positioning system. More specific information on the project is classified.

BIW Feeder (concept)

This vessel concept consists of a relatively small and fast shortsea transport container vessel equipped with automatic cargo handling devices: bridge cranes of hold width, and a mechanism for moving the containers from the side of the ship to the berth.

Figure 3 Automatic onboard cargo handling equipment



Twinstar (concept)

In this ship type, it is basically a question of transferring an automated warehouse into a ship environment. Automatic cranes, which can be easily controlled by computer, are used for positioning and handling of cargo in the hold of the vessel.

Depending on the size of the ship, 2-4 bridge cranes move side by side longitudinally onboard, handling ISO containers. The cranes move sideways over a width of 2 container rows. The loading and discharging of the ship is carried out at the aft, where the rails have been extended to reach the berth. The ship holds are equipped with patented container jigs for the lashing of 20-ft. containers on T-beam rails into compartments designed for 40-ft. containers. No manual cargo fastening is therefore necessary. On the other hand, the container jigs have to be mounted/dismounted manually on the terminal side.

This vessel concept was created by two Finnish brothers, Immo-R. and Raimo-R. Nordström. Its principal innovations were presented in the international press some 10 years ago already. The concept has since then been developed further, and is soon to be commercialised.

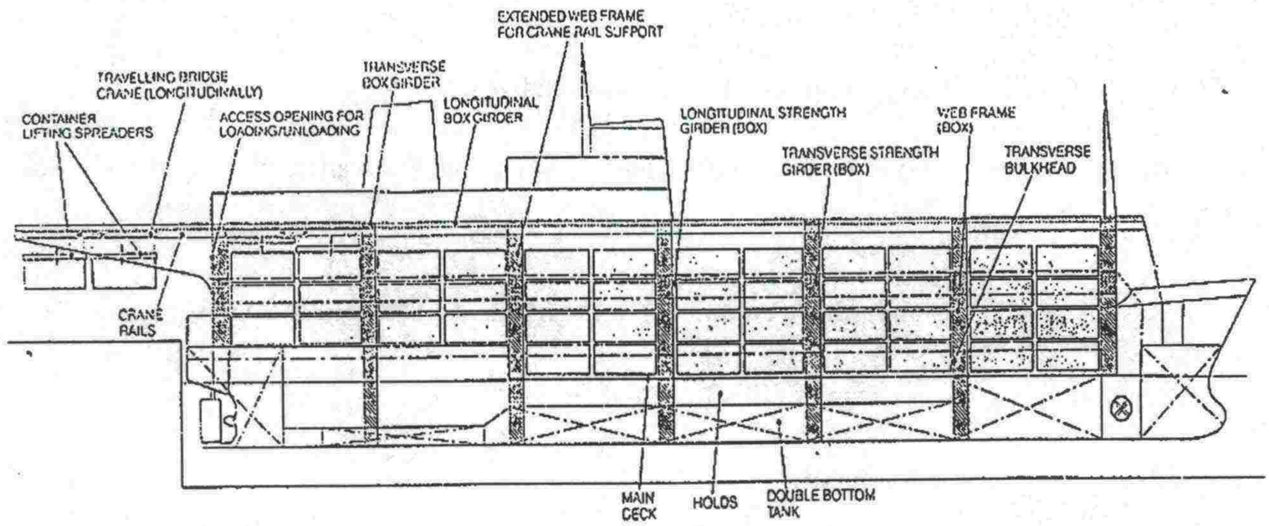


Figure 4 **Twinstar concept**

Advantages:

- Independent of onshore crane gear, which enables also the utilisation of ports with poor infrastructure, and, at the same time, eliminates one cost item since there are no lifting costs.
- Onshore cranes may also be used when necessary, as long as the deck hatches are removed.
- Cargo handling at sea, i.e., arrangements for efficient handling at port, is possible at least in theory.
- Simultaneous use of several cranes enables a high unloading/discharging efficiency; especially noticeable in smaller vessels.
- Lower manpower requirement.

Disadvantages:

- Requires great capacity of onshore handling at the aft end of the vessel through a very small area.
- Likely to be slightly more expensive than traditional vessels.
- Requires a stand-by system in case of failures of the automatic cranes, or the possibility of substituting gear.
- Positioning of non-standardised containers in the holds is a problem to be solved.
- Manual locking and releasing of 20-ft. container hooks.

Gigaideas portal crane (concept)

A relatively fast gantry-type crane is installed above the cellular hold of a container carrier. Its operation range covers the whole width of the hold. Due to the extension on the port side of the crane, the containers can be lifted directly between the ship hold and the berth. This type of solution is easily automated.

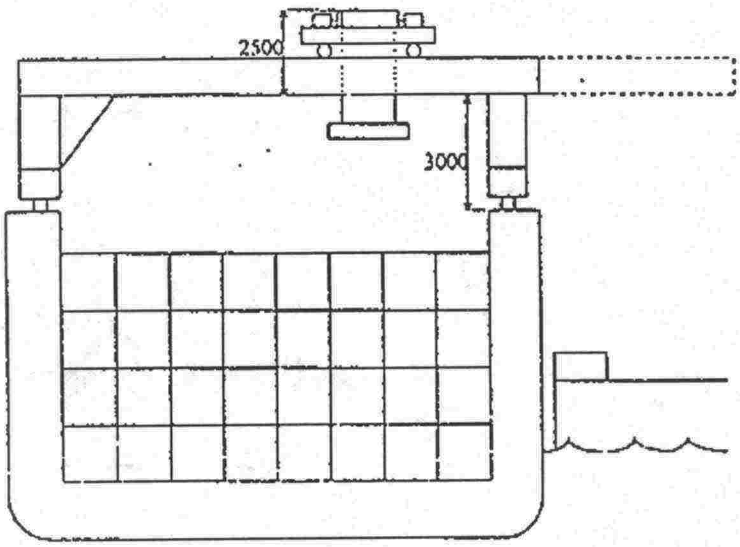


Figure 5 **Gantry crane application on container carriers**

The vessel and its loading / discharging system (concept)

This concept involves the patent (71908) granted to Jaakko Pöyry Oy in 1987. The innovation consists of a ship, with at least one loading/discharging side door on each side of the ship. A covered cargo space, without cargo hatches, is constructed on the main deck. There is a rail system in the ceiling of the construction for one or more bridge cranes moving longitudinally onboard the ship. There are hinges at the top end of the side door, and rails are installed on its interior surface for the loading section of the crane. The side door can be folded to a horizontal position so that the rails form an extension to the bridge crane rails. The loading section of the crane can be driven out to load the previously unitised breakbulk cargo from alongside the vessel, and take it to its final position onboard.

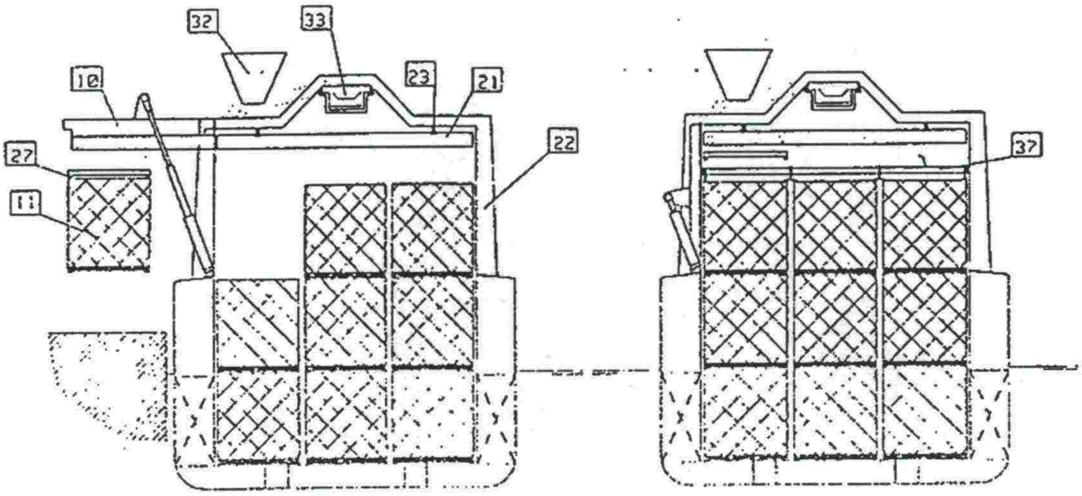


Figure 6 **The vessel and its loading/discharging system**

The Vessel and its Loading and Discharging System (concept)

The concept involves a patent (80416) granted to Jaakko Pöyry Oy in 1990. The innovation consists of a vessel with at least one opening on at least one side of the ship leading to the cargo space. There is also a cargo handling system with rails on the top of the hold for at least one bridge crane moving longitudinally. The upper part of the opening is designed to be considerably higher than the rails of the crane. There is also an intermediate loading deck with compartments, which can been moved vertically to enable positioning at the same level with the pier. Thus the cargo units can be driven inside the vessel and moved to their final positions.

This design presents a ship, which does not need active stabilising systems even if the size of the vessel is small. Neither does the whole length of the cargo space have to be raised, only enough to allow the operation of the bridge crane.

This invention is especially designed for the transportation of forest products, but it is also applicable to other cargoes.

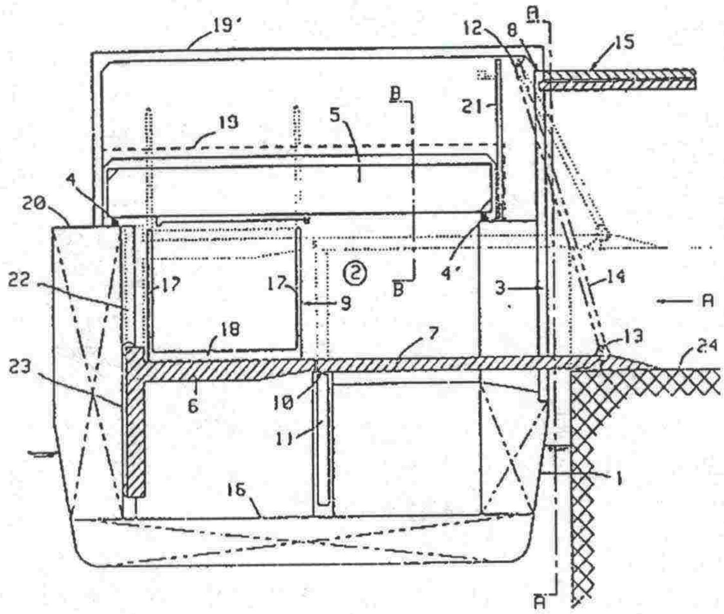


Figure 7 The vessel and its loading / discharging systems

Method for positioning the ship and its crane for loading (concept)

MacGregor-Navire (FIN) Oy was granted a patent (91510) for this concept in 1994. The design involves a system for adjusting the position of the ship and its crane in relation to the loading platform. The loading platform is equipped with a signal transmitter, e.g. a laser transmitter, and the signal receiver with detector is placed on the crane and onboard the vessel. The ship and the crane are positioned according to the signals by adjusting their movements so that the crane's loading attachment can grip the cargo. Furthermore, the method applies a flat situated on the loading platform. The loading flat is equipped with a counter-control device compatible with the control device of the loading attachment, by which the loading attachment can be positioned accurately in relation to the cargo, and the laser transmitter can also be on the loading flat.

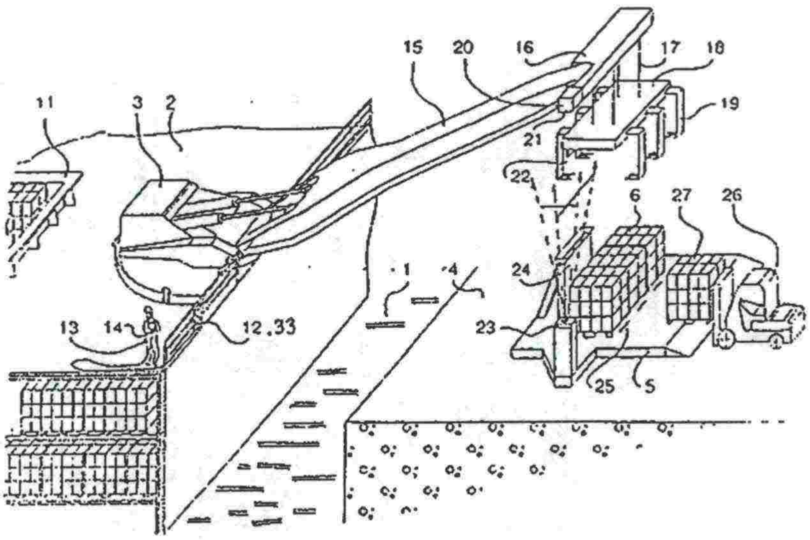


Figure 8 **Method for the positioning of the ship and its crane for loading**

Unit Cargo Carrier (concept)

The concept, for which a patent (97459) was granted in 1996, was created by Pekka Rapeli, and involves a carrier for the simultaneous transport of different types of wheeled vehicles, such as trucks, as well as containers and palletised bulk merchandise or other similar units of cargo. The essential idea is the cargo handling openings for transfer of cargo units to/from the cargo holds, as well as the cargo handling equipment and machinery for moving of cargo in the holds. The hold structure has at least two different sections. The first one consists of at least one cell structure and the second of container holds and/or pallet holds with guide tracks, where the containers and palletised heavy cargo are loaded/discharged mainly vertically. The first and second cargo hold sections are located beside each other at least partly, so that light cargo can be arranged in the upper part and heavy loads in the bottom parts of the carrier and ballasting can be at least partly avoided.

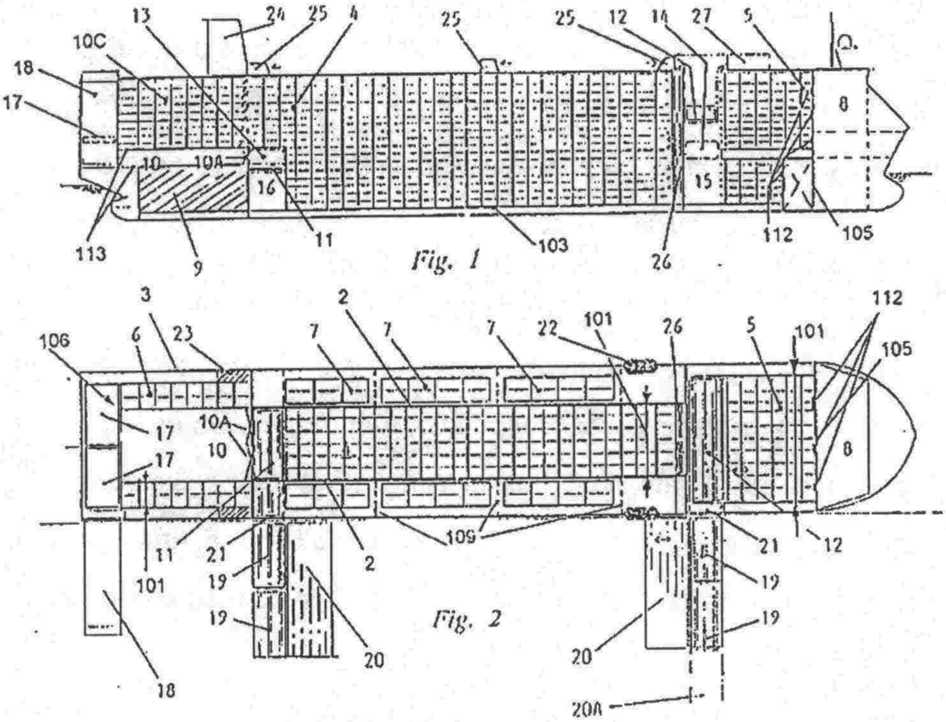


Figure 9 Unit cargo carrier

The use of a side door in a self-loading/unloading vessel may be problematic, as the ship trends to tilt when the cargo is moved on/off board. The simultaneous use of several cranes is especially complicated. The problem is more apparent in small vessels.

3.2 RoRo Handling

In RoRo handling the cargo is transferred onboard on wheels, either through the stern, aft or side ramps. The load is moved horizontally. The development of RoRo methods started in the late 1960s along with unitising and other innovative activities. The Finnish RoRo carriers operate on relatively short-distance routes. The loads are unit cargoes, cargo handling is fast, and the system is well suited for different kinds of cargoes. The relatively inefficient utilisation rate of the holds is a disadvantage, as the units cannot normally be stacked. The inefficient use of space is emphasised on a vessel where the moving of the cargo from one deck to another requires interior ramps or lifting equipment.

A more efficient use of space is possible with StoRo handling, when the cargo is taken to the holds on flats, stowed in place with lift trucks, and the flats then taken off the vessel. In certain special cases StoRo is quite efficient, for instance when heavy (e.g., heavy fine-paper rolls) and light specific weight cargoes can be combined to make efficient use of the tonnage and cubic space of the carrier. When applying the StoRo side system (SiDo) in RoRo handling, cargo is also transferred onboard with trucks through the side doors.

In addition to the above, there are also different types of combinations, such as RoRo/StoRo/LoLo carriers and, very commonly, train ferries. On example of the train ferries is “Railship I”, with an aft gate, an 84-ton capacity elevator for wagons, and railway tracks on three decks. Finnish RoRo carriers usually have elevators and lifts between the decks for moving of cargo units between the decks. Sometimes there may be conveyors for side loading.

Compared to LoLo handling, RoRo-loaded cargoes are considerably more heterogeneous. Furthermore, it is typical that during stowage the units have to be fitted in the holds. The automation of cargo handling is thus more difficult.

A common trend appears to be a decrease in the relative share of RoRo handling, because of the high shipbuilding costs and relatively inefficient utilisation of space. Still, in some applications, such as train-ship combinations and in shortsea traffic, RoRo handling may maintain its position.

“Scandic”

This, originally Swedish vessel/system operating in feeder traffic between two terminals, involves the mechanisation of handling of unitised cargo in containers. “Scandic” was the first RoRo carrier to make use of the aft ramp. The ship crew loaded and discharged the 20-ft. container units with 25-ton lift trucks. All containers were located in the holds transversely. The lower hold was automatically stowed with a conveyor (Running Beam Conveyor, RBC). The conveyor feeder from the upper deck was a transverse elevator located in front of the machine room bulkhead.

The advantages of this system included its independence of cargo handling at the terminal, and the efficiency and cost benefits achieved by using the ship's own experienced crew for the operation. On a small and relatively simple vessel a short turnaround time and frequent trafficking was achieved with this system. The system was in use for some years. The reasons for discontinuing may have been political, as the system would have eliminated the need for terminal workers.

Bore Lines of Finland used the system in its traffic between Gothenburg and Finland, and it may still be in use in some form. (Wijnolst et al., 1993)

Finnflow system

The Finnflow system has been used in the Finncarrier vessels, the first one of which was the "Finncarrier" constructed in 1969. This system used jumbo flats on which paper rolls, wood products, veneer, etc., could be loaded. The flats were moved onboard through the aft, stern or side ramps, either in rows on the deck in loading order, or on elevators for transfer to another deck. Early straddle carriers were used for the transfer. The tug-master towed semi-trailers and goose-neck terminal trailers onboard, which could be also used for the transfer of containers.

The jumbo flat carried to the elevator was lifted to the pneumatic "side-transfer wagon" on support pedestals. The cable-drawn transfer wagon was hauled together with the jumbo flat to its place, and the flat was taken off the wagon. This system was patented (see Figure J).

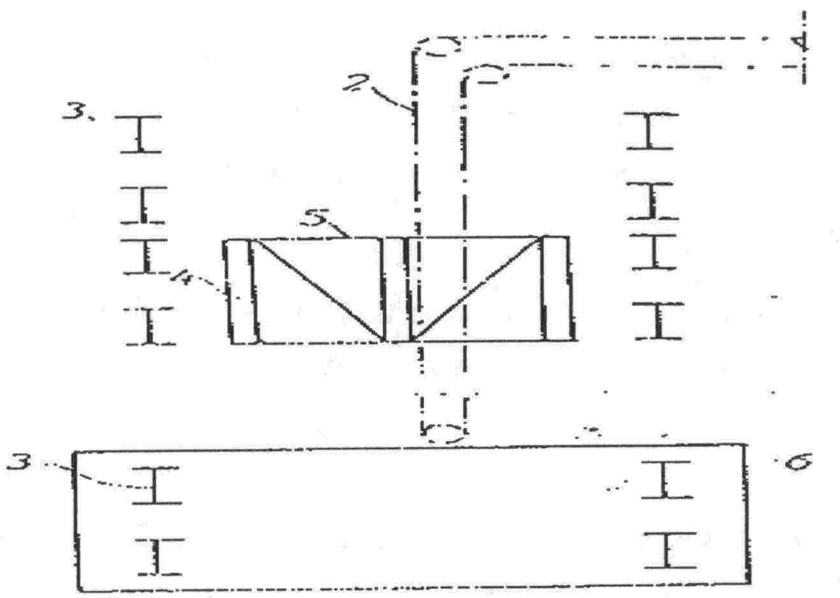


Figure 10 Diagram of the side-transfer wagon in a carrier hold

The Finnflow system still involved a lot of manual work, e.g. the handling of steel supports, use of vertical beams to avoid falling in the elevator shaft, the use of stowage pillows to support the cargo units, the application of different types of lashing to avoid cargo movement, the use of veneer board under the units, and use of container stackers when transferred with terminal tractors.

In 1987, the "Finncarrier" was lengthened, heightened and changed into a passenger/RoRo cargo and train carrier. Several features of the Finnflow system are still being used.

3.3 Barge Systems

3.3.1 Barges

A barge is a transport vessel with a simple structure, which has no machinery or crew. Traditionally barges are pushed or towed with different types of tug boats. The cargo handling system on barges can, in principle, be any of the ones used in ships, e.g., LoLo or RoRo. Cargo handling on barges can be mechanised or automated according to the same principles.

Barge characteristics can be utilised at least in two ways in barge systems:

1. Barges used for inland waterborne traffic are transferred on larger vessels for marine transport.
2. Loading the floating barge units/stores beforehand so that they can be picked up, with the aim to minimise cargo handling of vessels at port.

Neptun Carrier

The Neptun Carrier is an example of a more sophisticated barge than the conventional one. The vessel is a 10 000-dwt deck barge used for raw wood transport in the Baltic Sea. In principle it can be dump-unloaded, but due to the breakability of the binding wires of the raw wood, the bundles are normally unloaded with cranes. A deck barge has three cranes for cargo loading. The barge can be both towed and pushed. (von Bagh, 1988)

3.3.2 Push Barge Systems

In an ideal case, a push barge system includes a pusher and three barges. In the traffic between two ports, one of the barges is at the discharging end, one at the loading end, and one travelling with the pusher. The principle is that the time of the expensive pusher is fully used for transport, except for the time used for barge coupling. The relatively inexpensive barges, on the other hand, may stay in place during cargo handling. The system is well applicable to regular merchandise flows, with a high ratio of cargo handling to seafaring time.

Finnpusku

Finnpusku is given as an example of an operating pusher barge system, even though it is designed for bulk cargo transports. Finnlines Oy, Wartsilä Oy and Hollming Oy together carried out the design work for the pusher barge. The two pushers and five barges (14 000 dwt) used by Rautaruukki were built at the Hollming shipyard at Rauma (Finland), except for the barge hulls, which were constructed in Portugal.

Between the pusher and the barge there are coupling devices enabling a rigid joint, and therefore the combination behaves at sea like a conventional vessel. The time spent in exchanging the barge is normally only about an hour, which is comparable to the cargo handling time of a conventional vessel.

The barges have side-loading gates, and earlier their holds formed a one-piece compartment which facilitated bulk cargo handling during truck unloading. Nevertheless, in December 1990, the shifting of waterlogged dressed ore cargo carried in the open space caused a serious accident, in which the Finn-Baltic combination capsized in rough sea and eight people perished. After that, bulkheads were added to the barge structures and limitations were set for the transported loads.

Due to the operation areas, distances between the ports, and the large number of ports, it has not been possible to utilise the push barge system in ideal traffic configurations, and thus the theoretical figures of financial calculations have not been reached either.

Pusher barge system (concept)

Kvaerner-Masa Yards has introduced several versions for the utilisation of the basic idea of pusher barges. One of these concepts is the fast pusher barge combination for container transport. With a covered barge, it is possible to apply the system, e.g., for the transport of forest products and for intermediate storing.

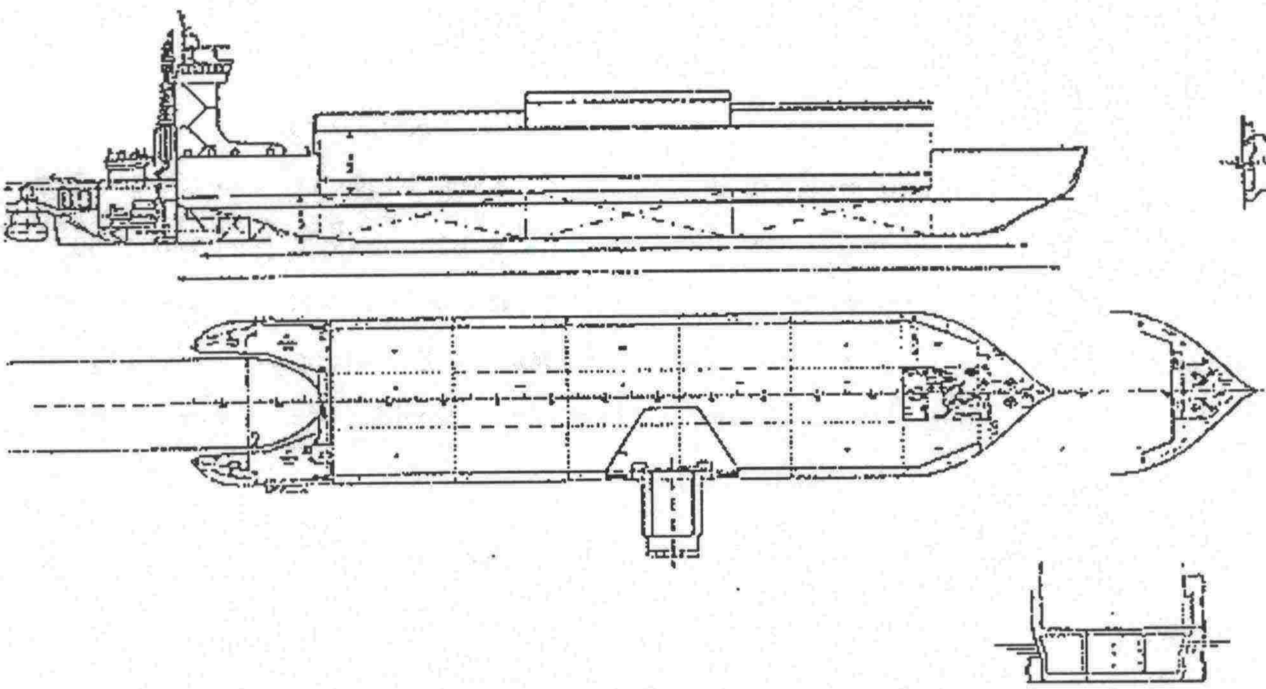


Figure 11 Pusher barge system

3.3.3 Barge-Mother Ship Systems

In the combination of barges and mother ship, the barges are either lifted or floated to the support ship. The barge-mother ship system has traditionally been the sea transport system for inland waterway barges. At least Valmet Oy and Oy Wärtsilä Ab has developed these systems in Finland.

The dock-type barge-mother ship is immersed with ballast tanks so deep that the barges can be floated to or from its hold. Apart from different-sized barges, this type of barge-mother ship can also carry other floating equipment or special cargoes.

LASH and Seabee vessels

The barge-mother ship systems developed in the 1960s and 1970s for inland waterway traffic/sea traffic were equipped with their own cargo units. In these vessel types, the floating cargo units (barges), containing diverse cargoes, are lifted from the aft of the vessel with its own crane to their place in the hold. The mother-ship alternatives are expensive, and at least the implemented LASH-versions have caused economic problems. The Finnish Kone Oy has delivered cranes to Seabee vessels.

Lifting device

Oy Wärtsilä Ab was granted the patent (50230) for this invention in 1976. The innovation is crane designed especially for lifting of different-sized floating barges or other objects. The lifting device has a chassis and a vertically moving lifting framework, to which the load is fastened. The aim of the invention was to create a crane that is operationally reliable and efficient irrespective of the size of the cargoes to be hoisted. This lifting device is designed particularly for the lifting of two different-sized cargo units, of which one is twice as long as the other. The loads are lifted onboard from the aft end.

The lifting device can be made so low that the entire device can be set onboard to move under the ship's deck. It is important for the structural strength of the vessel that there are no large openings on deck.

There is no information on the application into practice of this type of lifting device.

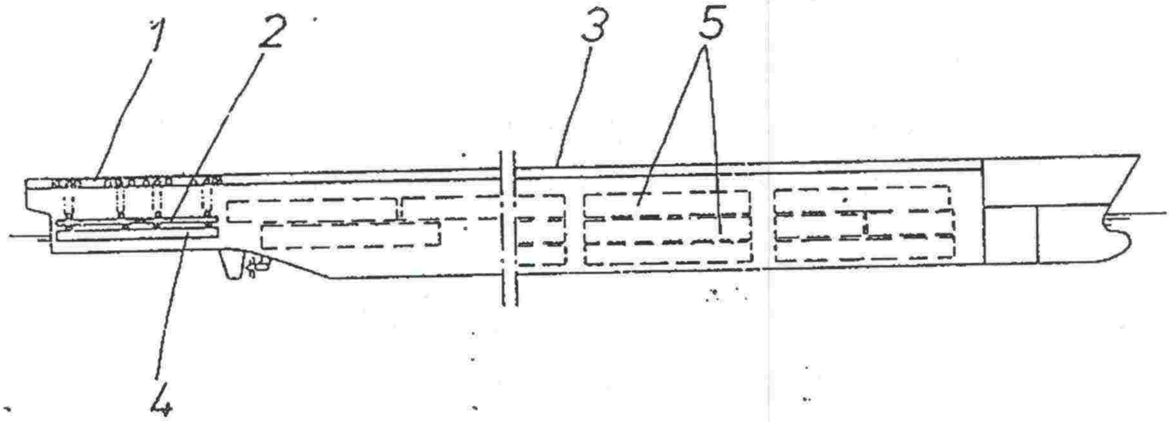


Figure 12 Lifting device

Floater

This immersing-type mother ship was presented by Valmet Oy in the 1970s. The system involves floating of the barges to the holds of the mother ship. The concept vessel was designed to carry six Tonava-Meri barges. The vessel had a very simple and inexpensive structure, but there is no information on whether a system like this was actually implemented.

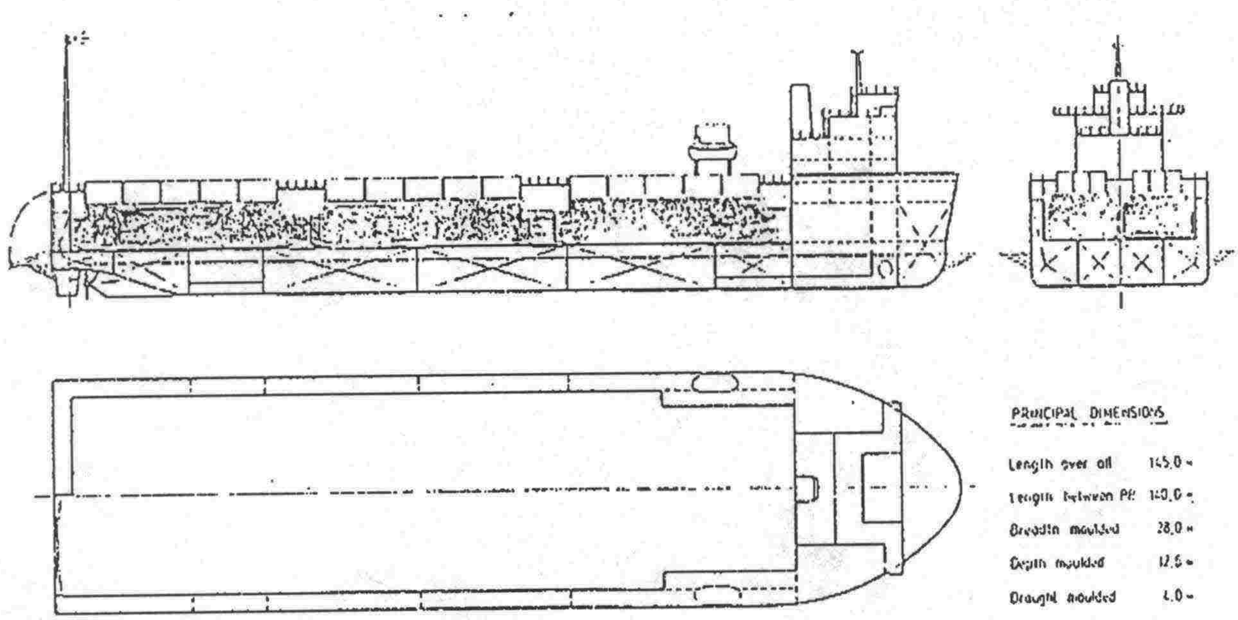


Figure 13 Floater vessel

Barge-mother ship (concept)

This is an example of the Kvaerner-Masa Yards concept of a dock-type container vessel with a semi-immersed hull, to which preloaded containers are floated on a barge. When the barges are in the hold, the ballast is pumped off and the barges are lashed to the deck.

Eurobarge (concept)

Kvaerner-Masa Yards has also proposed another system with a semi-immersed mother ship. Barges, e.g. of the optimum size for inland waterway traffic, can be floated to its side and fastened for sea traffic. The barges are in principle suitable for different types of loads. One possibility is to use the barges for intermediate storing of paper industry products before transport.

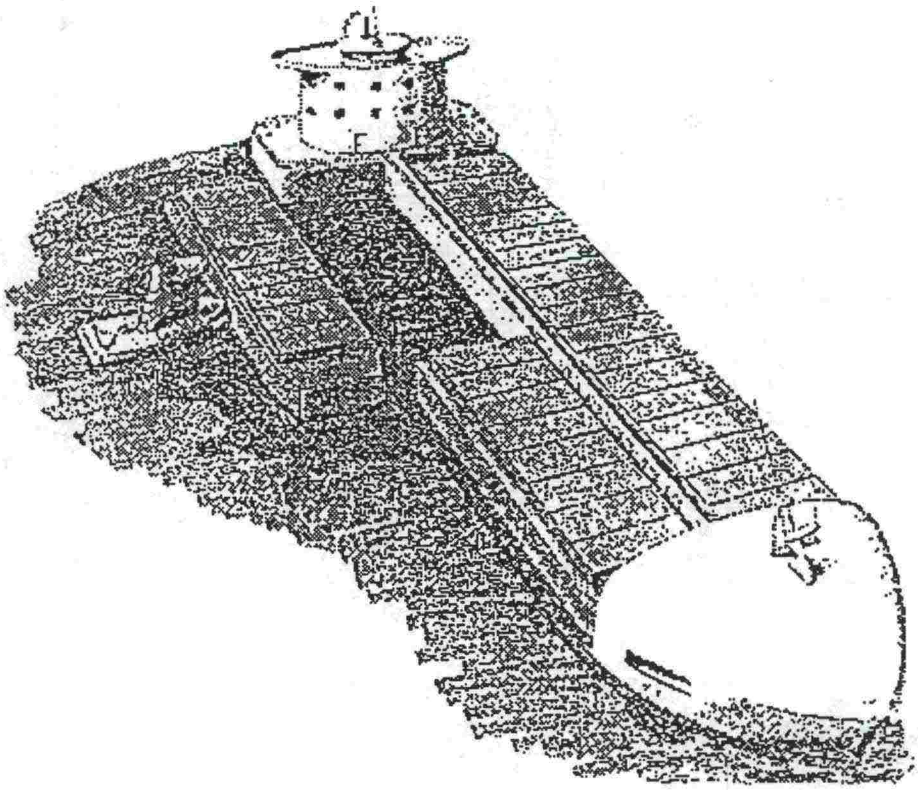


Figure 14 Eurobarge system

3.4 Innovations

3.4.1 Cassettes and Cargo Unit Systems

The basic concept of different types of cassette and other transfer systems is the unitising of various cargoes. The principal advantages gained by using cassette systems in cargo handling are:

- Larger handling unit size, which may increase the handling efficiency
- Easier mechanisation and better use of the cargo handling equipment
- Better use of ship gear capacity in some cases, e.g. stacking of unitised bulk cargo
- Less need for cargo lashing
- Possibility of automation.

The use of cassettes in the holds of RoRo carriers minimises the cargo securing requirement, as the cassettes can be stowed side by side. As the cassette homogenises the cargo, the variety of the handling equipment can be reduced, and cassettes also offer better possibilities for automated cargo handling in RoRo systems.

The cassette can also serve as an intermediate transport box, e.g. from terminal to terminal, which enables better capacity utilisation of the vessel, i.e. the stowing rate increases. Every small load does not have to be identified and positioned during transport.

Some disadvantages of the system are the tare weight of the cassette and the fact that it has to be loaded/unloaded separately.

The following section gives some examples of cargo units/cassettes and their handling methods.

Automatic control system of stowing and transfer vehicle and cassette (concept)

Oy Electrolux Ab - Kahete was granted the patent for this innovation in 1988. It involves the automatic control of a stowing and transfer vehicle, enabling the under-carriage of the terminal tractor to run underneath the cassette without bumping into its side-wall structure, and allowing it to be positioned in the desired place without colliding into the adjacent surfaces. The control system is based on the data transmitted by ultrasonic sensors about surfaces in front of them. The data are converted into correction impulses and transmitted to the turning mechanisms of the terminal tractor, which automatically turn the bogie axis to the correct angle for guiding the vehicle to the desired distance from the adjacent surface. When the under-carriage is driven under the cassette, the adjacent surfaces are the side structures of this last cassette. The cassette is driven with the automatic control system to a safe distance from the cassette next to it, and its final positioning close to the adjacent cassette is done manually.

This innovation also concerns the cassette on which the system is implemented. The side structures of the cassette have been adapted to the ultrasonic sensor pairs installed on the under-carriage. The upper sensors measure the distance to the side structures of the cassette when the under-carriage is driven under the cassette. The lower sensors measure the distance to the adjacent surfaces beside it during positioning, e.g. to the side structures of the cassette next to it.

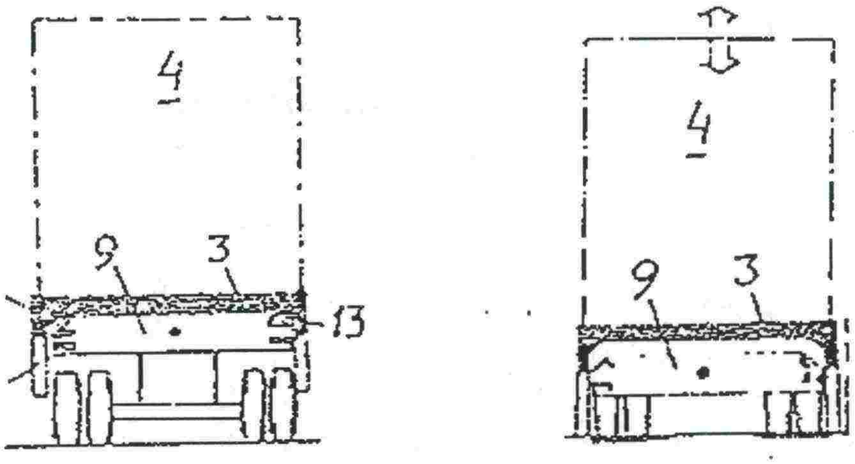


Figure 15 Automatic control system of stowing and transfer vehicle and cassette

Cargo unit (concept)

Jaakko Pöyry Oy and the Norwegian Upland Trading S/S were granted the patent for this innovation in 1991. The innovation concerns a rectangular cargo unit having a flat rack with end walls. The upper corners and correspondingly the lower part of the ends have gripping and guiding devices for stacking of cargo units and for their automatic transfer. The cargo unit has several shelves, whose length is approximately the same as the distance from one end to the other, and their width is at maximum the same as the flat rack's. There are also devices for fastening the intermediate shelves at the appropriate level on top of each other, and possibly beside each other, supported by the ends.

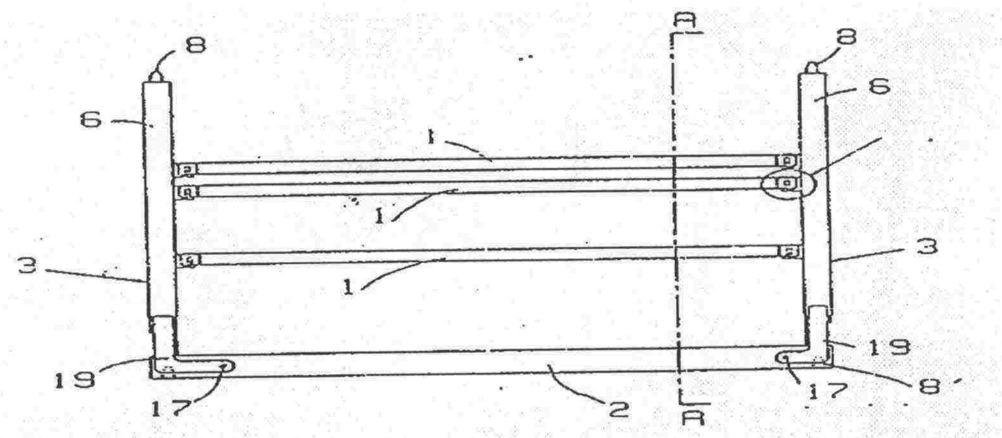


Figure 16 Cargo unit

Cargo handling system (concept)

Marita Järvinen Oy applied for a patent for this system in 1993. According to the system, an unmanned, remote-controlled terminal tractor, loaded with a cassette on legs, is driven on the ship deck to Position (I) close to other cassettes. Then the self-guiding support wheels within the bogie structure of the vehicle are lowered on the deck and the structure is turned 90°. Thereafter, the terminal tractor with its load is driven against another cassette to position (II). The wheels are turned in the original direction, and the vehicle is driven against the cassettes standing in front of it. The transferred cassette is left in this position, and the vehicle is driven from underneath to position (III).

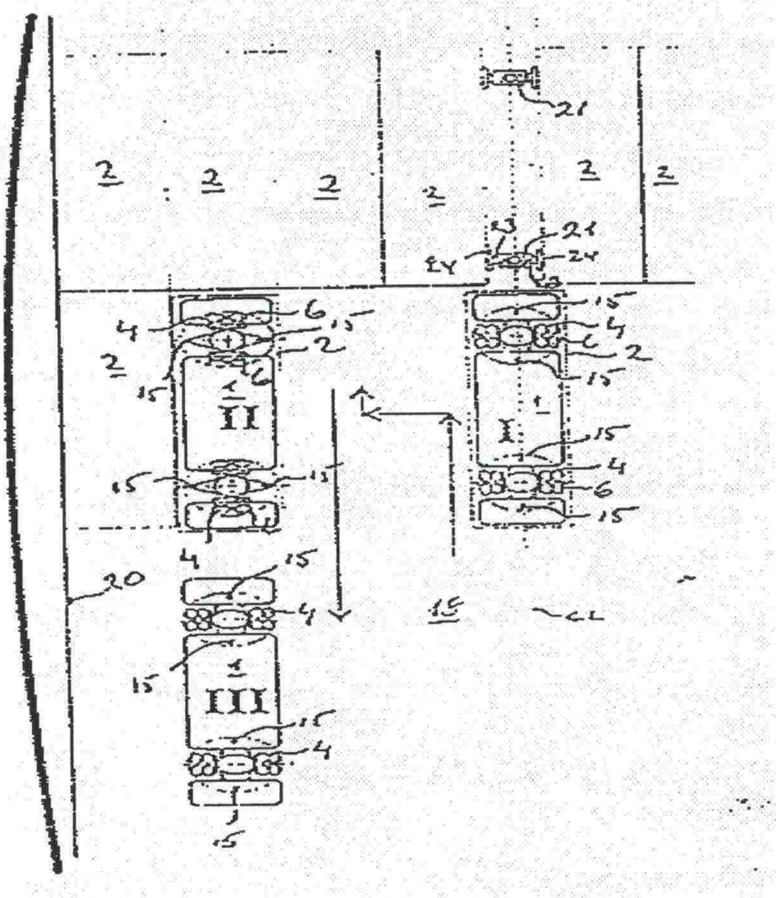


Figure 17 Cargo handling system

3.4.2 Elevator and Lifting Systems

There are several types of vertical elevators and lifting devices typically applied in RoRo handling for the moving of cargoes between decks.

This section presents two examples of lifting devices in cargo handling mechanisation.

Lateral ship loading system

MacGregor SF Oy applied for the patent for the lateral loading system in 1986. The system involves a cargo elevator on a double-bottom vessel. The elevator is installed in a vertical elevator shaft on the inner side of the ship planking, and moves on a guide beam which can rotate around its vertical axis. The cargo pallet on the elevator carriage installed at the end of a cantilever beam with a vertical swing axis can be moved from the shaft to the desired position outside the ship by turning the cantilever beam.

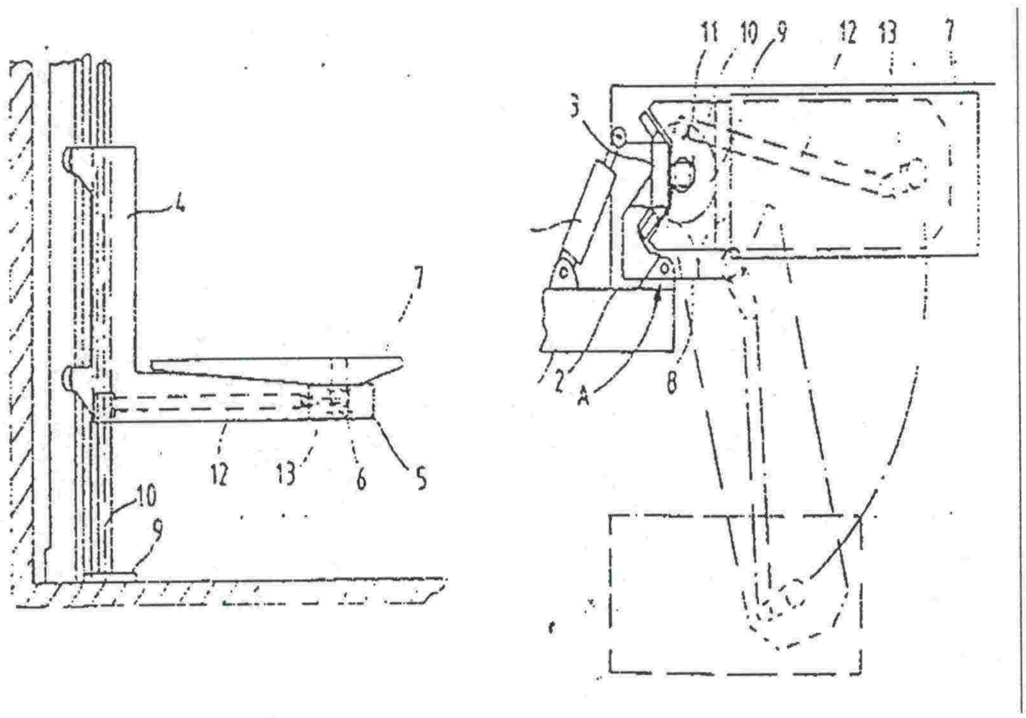


Figure 18 Lateral loading system of the ship

Lifting platform for ships

MacGregor-Navire (FIN) Oy was granted the patent (88729) for this device in 1998. The innovation is a lifting platform for use in ships. It consists of two loading flats on top of each other, lifting machinery for moving the platform vertically between the decks, and a control device for supporting and guiding the platform. The loading levels are connected to each other with a row of vertical support poles placed in the vertical middle level of the platform.

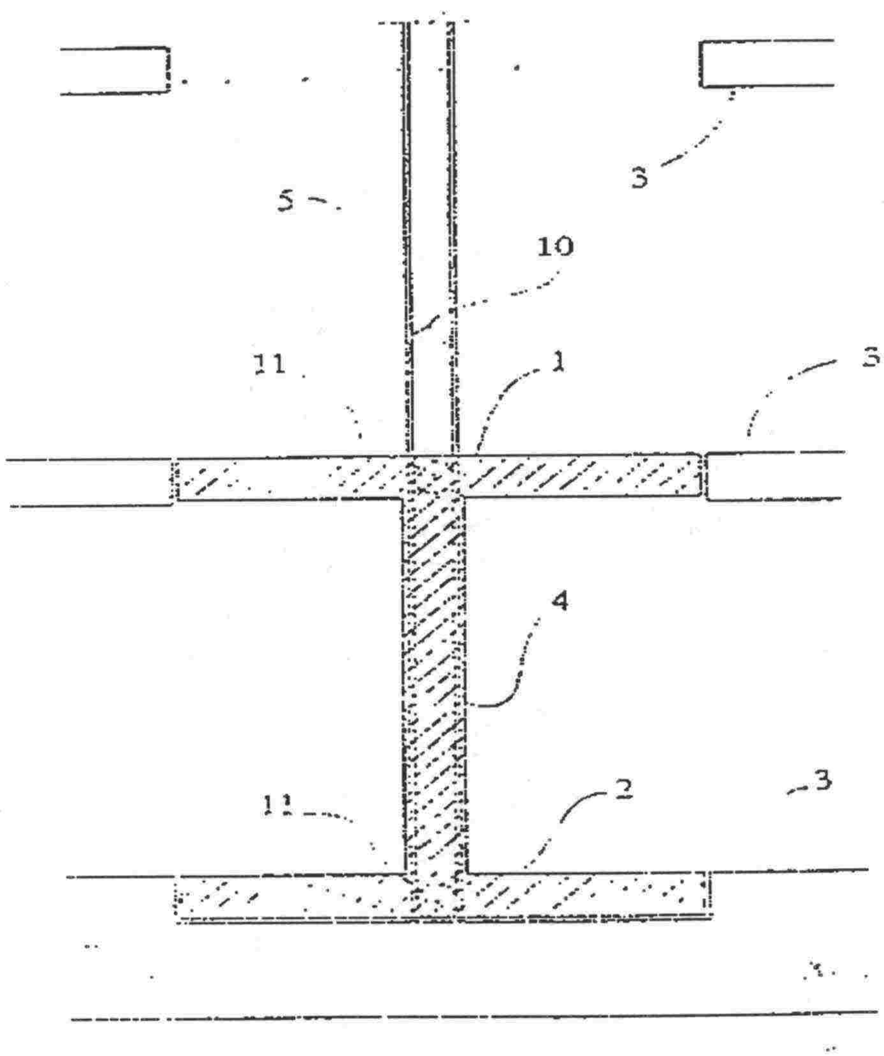


Figure 19 **Lifting platform on the ship**

3.4.3 Other Equipment

Conveyors

Conveyors are normally used for bulk cargo handling. Even in some Finnish RoRo carriers there are conveyors for cargo handling on the side of the ship, but only for limited volumes. In principle, there should be nothing to prevent the use of more robust conveyors for the transfer of bulk and unit cargoes from the berth to the ship holds. However, problems may arise from, e.g., changes in water level or variations in ship draught during cargo handling.

Automatic guided vehicles (AGV)

In principle it should be possible to use AGVs for cargo handling in the ship holds. Together with manipulators (see below), AGVs could also be adapted for use with forest products in StoRo handling. In the future, AGVs will probably be taken into use first in RoRo handling, because of all the available cargo handling systems, RoRo most closely resembles the onshore environments where AGVs are already being utilised. AGV characteristics suitable for ship cargo handling can be seen, e.g., in the Marita Järvinen Oy cargo handling system described above.

Manipulator

The manipulator was developed within the framework of the "Paper handling and transport 2000" project for the automation of paper roll handling. The gripping of the roll is automated so that the manipulator identifies the roll size and position, and is able to pick up the load without operator control.

The system enables the transfer of paper rolls fully automatically from point A to point B, e.g., according to data fed into the computer memory or a task list fed over the radio. The system applies the techniques used in AGVs. It is primarily designed for the onshore handling of rolls at the manufacturing plant, terminal and port. Still, its application in cargo handling in the ship holds is also considered possible. Rolls entering the ship holds with a side-door elevator would be unloaded from the lift and transferred to the hold according to the stowage plan without any manual control.

4. CONCLUSIONS

The advantages of mechanised ship cargo handling are indisputable. A good example of this is the worldwide success of container traffic. The mechanisation and automation development projects of cargo handling are primarily concentrated on port and terminal operations, even though some, mainly foreign onboard applications have also been implemented. As the study shows, innovation work has also been conducted in Finland, and new ideas have been presented for the mechanisation and automation of cargo handling onboard. Only a few of these innovations have so far reached the implementation phase.

Formerly, particularly before the breakthrough of the standardised container and at a time when there were no suitable cranes in the ports, ships were equipped with cranes of their own. Technically the installation of cargo handling machinery and equipment onboard has some disadvantages, as normally the ship hull needs to be reinforced to support the equipment and the weight of the load. Consequently, the deadweight of the vessel increases, the payload is reduced, and the construction costs rise. This poses a problem particularly for slender, weight-sensitive, rapid vessels, which would probably benefit most from efficient and automated cargo handling.

The investments in maritime transports and port operations are normally high and, because their life-span is long, the risks involved are great. At its worst, this may mean having to cope with a misguided investment even for a couple of decades. Installing cargo handling equipment on a ship or making a significant single investment in a tailored onboard system may have a more limited effect than an alternative investment at the terminal, e.g., if investment is concentrated in one vessel only instead of an onshore crane serving several vessels. Also the flexibility of the system may suffer, since the ship may be forced to restrict its operations to only some specific terminals . The secondary markets for a customised vessel may also be small, and the resale value low. In the long run, the benefits obtained from the investments are usually the decisive factor in all projects. The capital investment into the mechanisation and automation of ship cargo handling must also be profitable.

During the discussions and interviews conducted for this study, it was noted that one of the factors hindering the development work is that often there is no party which is able to view the transport chain as a whole or which otherwise has an interest in making wide-range investments into the development of the entire system. The new systems that have been implemented recently did, however, involve an active party of this kind, on whose needs the work for a feasible alternative was based. In order to develop integrated, comprehensive systems it would be most important to find a party that has a strong interest in developing new solutions, is able to change the current structures, and has sufficient power for the implementation of the project.

It also became quite obvious that there is a great deal of interest among the various participants in the transport chain, from engineering companies and equipment manufacturers to shipping agencies, in developing new alternatives. For the reasons discussed above, however, the projects that are actually implemented usually have to do with individual equipment or device innovations.

The paper industry might be a sector with sufficient risk-bearing capacity and interest to embark on integrated development. On the other hand, one of the interviewees felt that systems were being developed excessively on the terms of the paper industry, which was seen as an obstacle for development. The focus is on one-way export traffic instead of the whole transport chain, and the developed innovations do not apply to the other types of cargoes, although these make up the majority of the return traffic. Apart from the paper industry sector, a sufficiently large door-to-door transportation service agency might have the capacity to promote development activities.

The present level of automation in ship cargo handling appears to be relatively low compared to the industrial, commercial and even the service sectors. The overall development in these sectors brings pressure towards mechanisation and automation also in shipping operations. Computerisation is expected to find its way to almost all activities in the transport chain. Cargo unitising should be encouraged for a number of reasons. Besides decreasing the number of units to be handled and the physical handling times, unitising also facilitates the efficient use of computers for the automatic identification and positioning of the units, thus reducing the need for manual data management. The need for efficient data management may bring along radical changes in the physical organisation of cargo flow-through. It may, e.g., lead to the elimination of inefficient cargo handling systems onboard.

The fact that there are certain projects under way in Finland, dealing specifically with the automation of onboard cargo handling, may perhaps be seen as an indication of the future development trends within this sector.

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